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SOCIETY OF ENGINEERS.

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ESTABLISHED MAY 1854.

Journal and

TRANSACTIONS FOR 1891,

AND

GENERAL INDEX, 1861 TO 1891.

EDITED BY

G. A. PRYCE CUXSON,

SECRETARY.

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CONTENTS.

	PAGE
INAUGURAL ADDRESS OF THE PRESIDENT, WILLIAM NEWBY COLAM	1
THE BALANCING OF HIGH-SPEED STEAM ENGINES. By ARTHUR RIGG	23
A TRIAL OF A REFRIGERATING MACHINE ON THE LINDE SYSTEM. BY THOMAS BELL LIGHTFOOT	39
MODERN COAL GAS MANUFACTURE. BY CHARLES CLAUDE CARPENTER	61
PORTABLE AND PIONEER RAILWAYS. By JOHN KERR	89
VACATION VISITS	111
MACHINE STOKERS FOR GAS RETORTS. BY HENRY O'CONNOR ..	117
CORROSION IN STEAM BOILERS. BY JAMES HUGH PAUL, B.Sc. ..	147
THE DRAINAGE OF TOWN HOUSES. BY GEORGE MAXWELL LAWFORD	187
OBITUARY	215
INDEX	217

SOCIETY OF ENGINEERS.

ESTABLISHED MAY 1854.

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Hours, 10 *a.m. to* 4 *p.m.*; *Saturdays,* 10 *a.m. to* 1 *p.m.*

PLACE OF MEETING:
THE TOWN HALL, WESTMINSTER, S.W.

1892.

TRANSACTIONS, &c.

February 2nd, 1891.

INAUGURAL ADDRESS

BY

WILLIAM NEWBY COLAM,

PRESIDENT.

THE first and most agreeable duty of the President of the Society of Engineers upon assuming office always has been, and naturally always must be, to thank those who have done him the honour to elect him to that office. It is a dignity to which every member of the Society may aspire, but it is not a dignity which all can attain. It is a dignity to which I, doubtless in common with many others, aspired on joining this Society, but it is one which I did not by any means hope to attain so soon. And if there is one thing more than another which heightens my sense of obligation to the members and associates of this Society for having unanimously placed me at their head, or which increases my sense of gratefulness and renders my thanks the more earnest, it is the circumstance that I have been elected to the position of President within so comparatively short a time of my joining the Society. It is not duty alone that prompts me now to thank you most warmly for the honour you have conferred upon me; it is a far higher sense of appreciation of that honour that impels me to do so. And in thanking you, let me say that I fully recognise the responsibilities of the office, which responsibilities I am prepared to meet, knowing from experience as a member of Council that I shall be ably and loyally supported both by my colleagues on the Council and by the whole body of members and associates so long as my endeavours are directed to the promotion of the best interests of the Society. This being so, I ask you to accept my assurance that it is my intention during my year of office ever to study the welfare of our Society and to do my best to at least maintain it in the high position in which I find it, if not to raise its status still higher, as it will be my aim to do.

Following the time-honoured custom of my predecessors, I will first briefly outline the work of the Society during the past year, after which I shall touch upon engineering and scientific progress during the same period. If it should appear to some that my address is less complete than it should be, I can only ask their indulgence upon the ground that I only returned a few days since from a protracted professional tour through the United States.

Turning first to our Society, it is a matter of sincere gratification to me to be able to congratulate the members upon not only its continued, but its increased and increasing success. Our annual balance sheet is in every way satisfactory, and we have not for some years been in so sound a financial position as at the present time. During the past year our roll of members has been increased 8 per cent., and our number now stands at 448 members of all classes. The attendances at our ordinary meetings has moreover increased 10 per cent. over 1889. Our list of honorary members is now full, the prescribed number being twenty, and the prescribed qualification being that they "shall be gentlemen of distinguished scientific attainments." Among those on this list who have been most recently elected are Lord Armstrong, Dr. Anderson, Sir Benjamin Baker, Lord Brassey, Sir James Douglass, Sir John Fowler, Lord Granville, and Sir William Thomson. The expression of satisfaction on my part at the present favourable position and prospects of the Society would be incomplete were I to omit stating that in my opinion, as well as in the opinions of my colleagues on the Council, our favourable position and promising prospects are largely due to the consistently energetic working of our Secretary Mr. Pryce Cuxson.

The work of the Society for the past year ranges itself under two heads, namely, the reading and discussion of papers at our ordinary meetings during the session, and visits to works of engineering interest during the vacation. At our first ordinary meeting we had a most interesting inaugural address from my predecessor, Mr. Henry Adams, who largely dwelt upon the importance and necessity of technical education, noticing particularly the work of the Science and Art Department. He referred also to the wide field of enterprise that was open to the engineering profession beyond the shores of Great Britain. And this field it appears to me is still widening as countries become opened up, and as the demands for shorter and more direct routes of intercommunication increase.

We next had a paper from Mr. Ralph Hart Tweddell upon the application of water pressure to machine tools and appliances. This is the second paper on the subject with which we have been favoured by Mr. Tweddell, the previous one having been read in 1877. In the later paper he reviewed the progress of hydraulic machinery and appliances since the date of the earlier one, and gave us some practical information upon the subject of rivetting up large bridges *in situ*, the first bridge rivetted on this system being the Primrose Street Bridge in London in 1873. For this paper the Council awarded Mr. Tweddell the Bessemer Premium.

Our next paper was on weighing machinery and automatic apparatus connected therewith, by Mr. W. H. Brothers. He pointed out how the demand for accurate and reliable weighing instruments was on the increase, and he described many of the important improvements that had been introduced of late years into weighing machines. He then traced the gradual evolution of automatic weighing apparatus, from the simple but ineffective pendulum balance, to the Snelgrove electric self-operating and self-indicating weighing machine; I think most of us were surprised to find the large amount of engineering skill which had been engaged in perfecting such machinery. The author was awarded the President's Premium for this paper.

Mr. F. H. Cheesewright contributed the next paper, which was on breakwater construction. Passing in rapid review the various modifications made in breakwater construction upon the early systems, and pointing out their salient defects, the author then described the Lewthwaite system. He claimed for this system that it produced a perfectly vertical wall on any bottom, that it possessed perfect continuity, and that its cost was cheaper by three-fourths than any other known system.

Mr. Perry F. Nursey followed with a paper on the system of manufacturing salt *in vacuo* invented by Dr. Pick. The author first alluded to the primitive way in which the manufacture of salt was carried on in the present day by the open pan system, which he described, pointing out its disadvantages. He then described a salt plant which he had erected and worked under Dr. Pick's patent, and which gave excellent results as shown by samples of the products submitted. The process in question is based upon the Rillieux or triple effect system, but which is rendered applicable to salt manufacture by the important addition of a vacuum filter.

Sewer ventilation was afterwards treated of in an interesting paper by Mr. W. Santo Crimp, who reviewed much that had gone before on the subject as regarded investigation into the nature of sewer air and of the currents. He then described his own experiments in the same direction, the results of which led him to suggest that in the ventilation of sewers the fullest advantage should be taken of the wind as a motive power. Mr. Santo Crimp was awarded a Society's second premium for his paper.

An interesting paper then came before us on the treatment and utilisation of exhaust steam, by Mr. Percy Griffith. After pointing out the economical value of exhaust steam, and the little advantage taken of it, he described the various apparatus by which it may be utilised for many useful purposes. There is no question that in spite of the numerous systems extant for utilising exhaust steam, but little advantage is taken of it. This may be in some sort accounted for by a want of knowledge on the subject. This defect Mr. Griffith's paper should largely help to remedy. The Council awarded Mr. Griffith the Society's first premium.

The final paper of the year was by Mr. J. J. F. Andrews, on ship caissons for dock basins and dry docks. The history of the construction of ship caissons was briefly reviewed by the author, who then explained the relative values of six different types of caissons as to design, construction, method of working, stability of flotation and use. He concluded an interesting paper by describing an ingenious contrivance for taking the contour or invert of dock and basin entrances, when either wholly or partially covered with water.

During the vacation three visits to works were organised and carried out. The first was to the Thames Ironworks, Blackwall, where we were favoured with the opportunity of inspecting the *Blenheim* and the *Grafton*, two ironclads in course of construction there. The *Blenheim* is one of the new fast cruisers, and has a displacement of 9000 tons, with a length of 375 feet. She has a triple expansion engine of 20,000 horse power, driving twin screws. The *Grafton* is a cruiser of 7500 tons, having a length of 360 feet, and a breadth of 60 feet.

Our second visit was to the Royal Arsenal, Woolwich, where we inspected the various operations carried on in connection with the manufacture of ammunition for small arms and of heavy artillery. The laboratory department, the carriage department, and the gun factory, were successively visited, and owing to the courtesy of the officials the visit was rendered most instructive and interesting.

Our third and last visit was to the Crewe works of the London and North Western Railway Company. At these fine works, which cover nearly ninety acres of ground, we witnessed, first, the production of Bessemer steel in the converter house, after which we saw the Siemens-Martin furnaces, and then the process of manufacturing springs and fish-plates. The rail milling operation was then inspected and afterwards the points and crossings shops. The boiler shop and the department connected with it were later visited, and ultimately the locomotive erecting shops and the many other departments occupied in the production of those splendid examples of engine work.

It will thus be seen that we have had an interesting series of papers read during the past year, the subjects of which have been varied, and what is most gratifying, well discussed. I take this opportunity to urge upon members, what I conceive to be the duty of members, to use their best endeavours to either read or obtain papers. They cannot show their appreciation of the Society, or their interest in its welfare, in a more practical way.

It will also be seen that our visits have brought to us knowledge of varied interest, besides affording members opportunities for closer and more social intercourse than the ordinary meetings offer. I trust that these opportunities will be largely taken advantage of, especially in view of the privileges granted to the Society for the inspection of works, privileges which to the majority of members individually would be necessarily denied. I need hardly say that upon all occasions the Society has been received with the utmost cordiality and kindness, and no efforts have been spared to render our visits interesting and instructive.

Before closing the subject of the work of the Society, I may perhaps be permitted to state that at the commencement of the past year our rules and bye-laws were issued in a revised form. This revision was rendered necessary by change of circumstances since the rules were framed, some twenty-five years ago, and which changes in many respects affected the detail working of the Society; the rules were therefore carefully revised by the Council, and having been legally sanctioned, were approved by the members in special general meeting assembled.

I will now proceed to draw your attention to last year's progress in departments of practical science.

Electricity may now be considered to prominently occupy a most important place in the professional work of many, and in the minds of most of us. It is satisfactory to know that year by year the science of electricity is becoming more and more exact. We begin to know more of the relative positions of cause and effect: there is much less of groping in the dark, and of consequent disappointment in results. In other words, electrical science has been practically developed in many directions, and although it does not yet enable us to fully control the subtle agent we call electricity, we have a much firmer grasp of its attributes than we had a few years since. We have learned much of its hidden meaning, and are beginning to believe in the perfect subjugation of this, apparently untamable force of nature, in the future.

As regards the practical application of electricity to locomotion in this country, the most recent noteworthy incident is the opening of the City and South London Railway. This line commences at King William Street, London Bridge, and at present its terminus is in the Clapham Road, at Stockwell. The line is three miles and a quarter long, and it is laid with some steep gradients, and not a few sharp curves. The locomotives weigh about six tons each, and have Edison-Hopkinson motors. The current is supplied to them from a generating station, through a conductor carried on the permanent way between the rails. Engineers should endeavour to satisfy themselves as to the results arising from this interesting experiment in the application of electricity for rapid transit. The conditions of application are most favourable, and it is to be hoped that the commercial results will warrant the attempt, and prove satisfactory to all. The undenied success of such a line would doubtless herald many applications to Parliament for powers to construct many similar underground lines in and about London, and in other overcrowded cities. Indeed, several electrical railways have already been suggested both under and overground. The working of this line is doubtless a matter of interest to those in charge of our present steam-worked underground railways, on which travelling is for the most part rendered unbearable by reason of the discharged products of combustion into the tunnels. The City and South London Company is applying to Parliament for power to extend their present system, by a line from King William Street to the northern end of the City Road, Islington. The proposed new line will be about two miles in length, and will be connected with the present line by means of a subway for foot-passengers. The Bill, which asks for five years within which to construct the extension line, contains no exceptional clauses.

Perhaps the boldest electrical railway project yet suggested, is the line from St. Petersburg running north-east to Archangel on the White Sea, a distance of more than 500 miles. This scheme is under consideration in Russia, if it has not already advanced beyond that stage. It is proposed to furnish the electric current from a series of generating stations distributed along the line, and the cost of the undertaking, including rolling stock, has been estimated at an extraordinarily small sum per mile. In America there is a very strong feeling that electrical railways may be successful in the future. According to Captain Eugene Griffin, who delivered a lecture on the subject a short time since at the Franklin Institute, Philadelphia, the success of electrical propulsion has been established beyond a question. He says it is only a matter of time when it will replace horses in the majority of street railways. In a little longer time it will be the propelling power on all elevated railways, for they possess ideal conditions for the application of electricity. He holds, too, that it is within the bounds of possibility that steam roads will be worked by electricity. I consider that this power offers many advantages for suburban traffic in the vicinity of large cities, where conditions will admit of the overhead single trolley system being introduced and worked economically. The utilisation of hitherto neglected water-power will probably be one of the factors in determining the extension of electrical propulsion in this direction.

After some considerable experimenting with varied electric motors in America, it is generally considered that the overhead single trolley system is the only one at all feasible for street motors. In this country strenuous efforts are being made to produce the desired results with the storage system, which in America has produced the worst results. The objections raised against the overhead wires in many of the towns and cities where it has been introduced, have induced Mr. Mansfield, of New York, to still direct his attention to developing the spot system. A continuous insulated conductor is buried in the ground, and short branches are run from it to the road bed at short intervals along the track, but contact is open at all times, except when a car is passing over any particular spot. An electro-magnet is used to raise a pivoted arm in a box in which these contacts are placed; and it not only closes the connection between the main conductor and branch, but establishes also a sliding contact with a rail mounted on the underside of the car. The current returns through the motor and rails to the supply station. As the car passes over the track it cuts its motor into circuit first at one contact spot, and then before breaking connection with that spot, establishes connection with another. Nothing is to be seen along the track except the spot boxes.

A really efficient primary battery appears still to be a desideratum. About three years ago Mr. Nursey read an exhaustive paper on the subject before the Society. He brought before us all the then known forms of primary batteries for illuminating purposes, and his conclusion was that there was not one which embodied the conditions which he laid down as a *sine qua non* a practical primary battery should fulfil. Since Mr. Nursey read his paper there appears to have been little or nothing further done until last year in this class of generator, or, if done, it has not been published. During last year, however, three new primary batteries made their appearance. The first of these was the Renard, which has for its electrodes platinised silver and zinc, the exciter being a solution of chromic acid, hydrochloric acid, and sulphuric acid. The electrodes were suspended in tubes, up which the solution was forced by air pressure, produced by a small hand pump, when the light was required, the pressure being relieved when it was desired to extinguish the light. There was thus no waste when the light was not required, besides which several other advantages were claimed, which, however, have not succeeded in bringing this battery greatly into use, if at all. The second battery was that of Weymersch, which is a two-fluid battery, the carbon elements being suspended in porous cells containing a special but cheap acid exciting solution, and the zinc elements being suspended in acidulated water surrounding the porous cells. High illuminating power, combined with low cost of maintenance, were the chief advantages claimed for this battery. The third battery came out in Italy, and was of simple construction, consisting merely of conical vessels of cast iron and porous earthenware, with nitrate and sulphuric acid. The cones were placed one in the other alternately and partly filled with acid, the iron cone with nitric, and the porous cone with sulphuric acid. Neither of these three devices, however, appear to advance the question of practical electric lighting beyond the stage at which they found it.

Electric lighting is gradually extending, although not at the rate that was at one time anticipated. The various electric lighting companies have to a large extent acquired rights in the more central portion of London, and are by degrees adding to their list of private customers. One of the most interesting central generating and distributing stations is that of the Metropolitan Electric Supply Company at Sardinia Street, Lincoln's Inn. The engines and dynamos are all of the Westinghouse type. No great advance has as yet been made in public street lighting in the metropolis, for, as far as I am aware, there are not more than about a thousand arc lamps in use, and they for the most part belong to railway companies and private owners. The supply of the current is in most instances carried on by means of underground wires; only about three companies are using overhead wires, the others having laid their mains below the surface, or carried them alongside railways. The number of theatres lighted by electricity is increasing, and churches are slowly following in their wake.

The St. Pancras Vestry has taken steps to provide electric lighting for the parishioners, this being the first body in London to undertake the lighting of their own district. A site for a central electric generating station has been secured, and the foundation stone of the building was laid in November last. The installation will serve the south-western portion of the parish, and it is intended to follow this one by other installations to serve the remainder of St. Pancras. The engineer for this work is Prof. Henry Robinson, one of the past presidents, and he has adopted the continuous current, and has fixed the electro-motive force at 110 volts, to suit glow lamps. The mains will be laid upon the three-wire system, by which arrangement the current will be transmitted from the central station at 220 volts along the two outside wires, whilst the third wire will be kept at an intermediate potential, only differing from that of either of the outside wires by 110 volts. In our public offices the electric light is being gradually adopted. It was partially introduced into the Houses of Parliament some time since, and its use there has been recently extended, although the actual chambers of both Lords and Commons are still lighted by gas. In the Law Courts, to a large extent, and in the Public Record office, the lighting is electric, although here again it is not universal. The first large public building lighted entirely by electricity is New Scotland Yard, the new central offices for the metropolitan police, situated between Whitehall and the Thames Embankment. In this building electric lamps are fitted in every room and corridor. There are about 1260 glow lamps, representing in the aggregate over 20,000 candle power.

It is surprising how very few cities in America have availed themselves of electricity for lighting the streets, especially when it is remembered that they are not hampered by restrictive legislation such as existed in this country up till quite recently.

Electric welding has been for some time past an accomplished fact. Invented by Prof. Elihu Thomson in America, its feasibility was first demonstrated in that country. The process was to be seen at the Paris Exhibition in 1889, and during last year it was introduced into this country. The principle involved is that of causing currents of electricity to pass through the abutting ends of the pieces of metal which are to be welded, thereby generating heat at the point of contact, which also becomes the point of resistance. At the moment of heating, mechanical pressure is applied to force the parts together. As the electric current heats the two pieces of metal to the welding temperature, the pressure follows up the softening surfaces, until a complete union or weld is effected. As the heat is first developed in the interior of the parts to be welded, the interior of the joints is as efficiently united as the visible exterior. With this process it is found possible to accomplish, not only the common kinds of welding of iron and steel, but of metals which have hitherto resisted attempts to weld them, and which have had to be brazed or soldered. This process may prove of great use where it can be worked as a commercial success.

The application of electricity to industrial purposes is also extending in other directions. In fact, it would seem from some recent developments that electricity is gradually invading the whole domain of commercial chemistry. In Switzerland, a factory for the manufacture of chlorate of potash by electricity has been established. Soda is being obtained by electrolysis of sea salt. In France, the electric bleaching of paper pulp is being carried on, while from Germany we are promised electrically made soap. The transformation of wood into paper pulp by the electrolysis of a salt solution in which sawdust is immersed has been effected, and steps are being taken to establish the industry. The production of caustic soda and chloride of lime from salt by means of electricity has recently been satisfactorily demonstrated in this country, and the process is in operation at a large paper mill on a practical scale. Tanning by electricity was demonstrated last year at works in Bermondsey, where an extensive tanning plant has been laid down. The ordinary steeping process occupies on the whole from three to four months, and requires a large number of pits, whereas the electrical process was shown to reduce the time to a remarkable extent, and the plant occupies considerably less room. The latter consists of eight wood drums 11 feet 6 inches in diameter by 8 feet broad, revolving on horizontal axles. A current of electricity is passed into each drum through the axles, the conductors being laid around the interior of the drum.

The hides are prepared in the usual way, as for the ordinary process of tanning, and are then placed in the drums in a tanning solution. The drum is then closed and revolved by machinery until the raw hide has become converted into leather. It is claimed that by this process light calf-skins can be tanned in twenty-four hours as against from four to six months by the ordinary process, light ox-hides in seventy-two hours as against from six to seven months, and heavy ox-hides in ninety-six hours in place of from twelve to fifteen months.

Before quitting the subject of electricity, it may prove interesting if I draw attention to a few scientific matters in connection therewith. The painful circumstances connected with the execution of a criminal by electricity in the United States have called forth many opinions as to the action of electricity upon the human body. As yet it is an unsolved problem as to what takes place in the human organism to produce death from an electric current. Mr. John C. Henry, writing in one of the electrical journals, says:—

"I have held a theory in regard to this subject so long that I have forgotten whether it is original or not. It is, that when a being suffers death from an electric shock, it is a pure case of internal rupture or explosion from the generation of gas or vapour. In support of this view I would refer to the many cases in which telegraph poles are torn to pieces. My observations on the plains, where it is of very frequent occurrence, is that the lightning follows the moist portion of the pole, which is the core or heart; in this case the moisture is vaporised, and an explosion occurs. The high resistance produces heat, the heat, in turn, steam, and the steam an explosion. It has been suggested that death is caused by a magnetic or electrolytic effect. I know of no experiment that would demonstrate either of them, or heat, to be of any more force from an alternate than from a direct current, and yet our sages say the alternate current is the more dangerous. If this be true, we should grope around in the dark to find the other effect that may be used in the service of man."

An interesting fact is recorded as to the action of the electric light upon insect life. Prof. Lintner, the American State entomologist, has made a microscopic examination of the insect collection of a single electric light, and estimates that the débris which he inspected represented 33,000 insects. As many of the smaller forms of insect life probably constituted the large portion of those attracted to destruction by the light, he believes that the average number of insects destroyed in a night by a single electric light is nearly 100,000. The large portion of Prof. Lintner's specimen collection from one light consisted of minute gnats, midges, crane-flies, and similar small two-winged insects. No mosquitoes were discovered among the victims, as they were not attracted by the light. There were, however, large numbers of plant-beetles, which are injurious to vegetation, particularly of one small species, a handsome green gassid. A number of moths, and one of the leaf-rollers which make such havoc during the American fruit season, were found, as well as other species of the same family.

"The electric light," to quote Prof. Lintner, "will undoubtedly prove an active agent in the reduction of insect pests, and also furnish entomologists with many rare specimens, and with many species never before seen."

Although the electric light is largely fatal to insect life, it is not injurious to vegetable life. It is well known that the late Sir William Siemens cultivated flowers and fruit by the aid of the electric light. The effect of the light on the flavour of the fruit was once the subject of an observation made by our respected engineer, Sir Frederick Bramwell, to an audience, whom he informed that the taste of the grapes was excellent, although he thought he detected a slight flavour of "currents" in them.

I will conclude my observations on electricity by a reference to the discovery of an electrical plant. This strange plant, which was found in the forests of India, appears to possess to a very high degree remarkable magnetic power. It is said that the hand which breaks a leaf from it immediately receives a shock equal to that produced by an induction coil. At a distance of about 20 feet a magnetic needle is affected by it, and will be quite deranged if brought near it. The energy of this singular influence varies with the hour of the day. It is all-powerful about two o'clock in the afternoon, but is ineffective during the night. At times of storm its intensity augments to striking proportions. During rain the plant seems to succumb, and it bends its head during a thunder-shower; it remains then without force or virtue, even if sheltered with an umbrella. No shock is felt at that time in breaking the leaves, and the needle is unaffected beside it. It is said that never by any chance is a bird or insect seen to alight on the electric plant, an instinct appears to warn them that they would find sudden death. It is stated that where it grows none of the magnetic metals are found—neither iron, nor cobalt, nor nickel—a proof that the electric force belongs exclusively to the plant.

As it is generally now admitted that some more efficient means of transit is needed in our streets to supersede the horse, it may be of interest to know what success has attended the introduction of mechanical motors other than those referred to as worked by electricity. Among motors that have been tried and failed, and others that are now about to be tried, or are only in a state of embryo, are the following:—Locomotives worked by steam, by compressed air, by gas, by steam storage; cars propelled by air compressed at a main station and delivered through pipes to the cars at sections of the routes; cars worked by compressed air delivered from a main station to small air engines placed under the road surface at stated distances. The object of the distributed air engines is to communicate a rotary motion to a hollow shaft submerged in a tube under the road, which in turn is to convey motion to the cars, through a slot in the road surface.

The only form of transmitting power which has been gradually making headway during the last six years is that known as the cable system.

This may be described as an arrangement which enables street cars to make use of a wire rope concealed in a tube below the road surface and kept constantly moving in one direction at a given maximum speed, from a power house. By means of gripper mechanism connected with a car and working through a $\frac{5}{8}$-inch slot in the road, a driver can cause his car to be propelled at the maximum speed of the cable, or at any reduced speed desirable.

In the United States most of the large cities have adopted this system for propelling cars with marked mechanical success. In one city as many as seventy miles of this system may be seen carrying on the traffic at speeds varying from six to fourteen miles per hour. Melbourne has a most important installation of forty-two miles, and Paris has just completed a system. Many more most important districts are now becabled, such as Broadway and Third Avenue, New York.

In Great Britain I have been mainly instrumental in developing and constructing lines by this important system, with the result that we have important illustrations in London, Birmingham, and Edinburgh, and I am just commencing another very important installation in London. Last Session, Parliament granted powers for constructing twelve miles of iron-tube tunnel under the streets of Glasgow. The motive power is to be a continuously moving wire rope, travelling at a high speed. Application is also being made in the present Session of Parliament for leave to construct a tunnel between South Kensington

Station and St. Pancras Station. In this case, also, wire rope is being considered as the means of imparting motion to the train. The working of the cable system in Great Britain has demonstrated that in very many places a great saving may be made over horses by its introduction.

Turning next for a short time to the subjects of mining and metallurgy, I would first bring under your notice the important discovery of the rare metal uranium which took place about eighteen months since. It has been found in the form of a lode at Grampound Road, Cornwall, and its discovery has been followed by the practical development of this important find. This is believed to be the only known regular lode of the metal in the world, as it has previously been found only in isolated pockets and patches. Not only have steps been taken to develope the lode and to work the mine, but works for producing the metal from the ore have been fitted up. To obtain the metal, the ore is first roasted and then crushed to a fine powder; it is then dissolved in acid, and precipitated by the aid of chemicals. The precipitate is then filtered, and afterwards dried and pounded, the result being a yellow powder, which is the commercial oxide of uranium. There are mainly two oxides of this metal, the sesqui-oxide, which is yellow, and the protoxide, which is black. The sesqui-oxide is employed in glass manufacture to produce a golden colour, and in conjunction with other minerals, opalescent tints. The protoxide is used in the production of costly black porcelain. Uranium occurs in the Cornish lode as a sesqui-oxide, containing from 18 to 29 per cent. of metal. The yield is stated to be about 18 per cent. from the lode near the surface which is now being worked, the products being sold to glass manufacturers, the market price of the metal being about 2000*l.* per ton. Other applications of the metal are in contemplation. It is proposed to substitute it for gold in electro-plating, and as it possesses a high electrical resistance, it is expected to prove useful in electric light installations.

A still more important discovery than the foregoing is reported to have been recently made in France, namely, that of gold. According to 'Iron,' this discovery has been made in the departments of the Hautes Alpes and Isère, where are situated the villages of Grand-Clos, Challanches, Allemont, and Traverse. Mines bearing the names of those villages exist there on the main route from Grenoble to Briançon, and have been worked for a great number of years for silver and lead. These mines, moreover, are of great antiquity, and local tradition has it that they were worked by the Saracens, and there is apparent truth in this belief from the very peculiar manner in which the ore has been taken out. The present owners have opened up some of the old workings, under the supervision of an expert having a good knowledge of auriferous mining, who came to the conclusion that the deposit was largely one of gold. Assays were made, with the result that a considerable body of ore was proved to be auriferous, carrying no less a quantity of gold than four ounces per ton of mineral. No mention is made, in either the returns to the Government or the old records, of any gold having been obtained, the only notice taken being that of silver, lead, nickel, and cobalt. Further explorations have, however, proved the existence of a deposit of superior anthracite coal and asbestos. In fact the whole of the range of mountains is said to be an immense deposit of mineral wealth. The average of some of the lodes is reported to be 50 per cent. of metallic lead, carrying about ten ounces of silver per ton of ore. In others, the lead is not above 10 per cent., but in these lodes the silver ranges from 60 to over 150 ounces per ton. In the auriferous veins the gold is said to range from two to seven ounces per ton. The most remarkable thing in connection with this deposit of mineral wealth is that no suspicion of the presence of gold appears to have entered the minds of the local miners, for some buttons of silver, the result of assays for that metal, contained over three-quarter ounces of gold, and over 62 ounces of silver per ton of ore. The mines being situated in the Alps, there are enormous supplies of water to facilitate the treatment of the ore, whilst no expensive mining or drainage operations are necessary in consequence of the mineral deposit being over 3000 feet above water level.

Some of us may have seen examples of metallised leaves and insects, of which there are some elegant specimens extant. The process of thus preserving objects belonging to the animal and vegetable kingdoms is still being followed up. Among others, Dr. Variot, a Frenchman, has further developed the idea of preserving dead bodies by a galvano-plastic method. To facilitate adherence of the metallic deposit, he paints the skin of the subject with a concentrated solution of nitrate of silver, and reduces this with vapours of white phosphorus dissolved in sulphide of carbon, the skin being thus rendered dark and shiny. The body is then ready for the electric bath, which is served by a thermo-electric battery, giving a regular adherent deposit of copper, if the current is properly regulated. With a layer of half to three-quarters millimetre, the envelope is solid enough to resist pressure or shock. Dr. Variot further incinerates the metallic mummy, leaving holes for the escape of gases. The corpse disappears, and a faithful image or statue remains. This method differs from that of M. Kergovatz, a chemist of Brest, who encases the body in a skin of copper, and thus preserves it. It is also different from the process of the late Prof. Motta, of Turin. This learned Italian spent a fortune in developing his process, and died poor, taking the secret of preserving the human body with him to the grave. By Signor Motta's process, the body was submitted to a chemical manipulation, by which its organic substances were destroyed and replaced by metal, the body being completely metallised. The late professor left behind him a large collection of metallised heads of adults and children, as well as metallised flowers, leaves, ostrich feathers, and lace.

The search for and the discovery of coal in Kent, is a subject which has been brought prominently to the front of late. Just a year ago its discovery was announced by Mr. Francis Brady, the engineer-in-chief of the South Eastern Railway and the Channel Tunnel Company, under whose direction operations were conducted at a point on the South Eastern Railway adjoining the experimental heading for the proposed Channel Tunnel. Coal was reached on February 15th, 1890, at 1180 feet below the surface. It came up mixed with clay and reduced almost to powder by the boring tools. A small quantity of clean bright coal found in the clay was tested by burning, and proved to be of good bituminous character. The seam was struck after passing through 20 feet of clay, grits, and blackish shales, belonging to the coal measures, which at that point lie close under the lime, there being only a few intervening beds of sand, limestone, and black clay separating them. The correspondence of the deposits with those found in the Somersetshire coal-fields is said to be pretty close, the difference being in the absence of the red marl, at the Shakespeare boring. The lines of bedding in the shale are distinctly horizontal, which is accepted as an indication that the coal measures will probably be found at a reasonable depth along the South Eastern Railway to the westward. From a geological point of view the discovery is extremely interesting. From a commercial point of view its importance yet remains to be seen, as the question whether there is a sufficient thickness and continuity of good coal to pay for working is at present unsolved.

The minds of some of those practically interested in the metallurgy of iron and steel are sometimes exercised as to the future prospects of the industry with which they are connected. One of the most practical and far-seeing authorities in this connection, the Hon. Abraham Hewitt, an American ironmaster of high repute, has taken the subject in hand, and has treated it in a skilful and judicious manner. His observations on the subject occur in an address which he presented to the Iron and Steel Institute of Great Britain at the meeting held in New York last year. In that address Mr. Hewitt struck out on a line at once novel and bold upon the question of the amount of the future requirements of the world for iron and steel. He argues from extremely plausible premises, that at the end of another ten years the world's requirements, estimated in pig-iron, will amount to 35,000,000 tons, or 11,000,000 tons more than at present. Of this, he reckons that the United States will supply forty-five per cent., Great Britain, seventeen-and-a-half per cent., and Germany, France, Belgium, &c., twenty-seven-and-a-half per cent. This division gives to Great Britain and Europe an increase of 3,000,000 tons. So far as Great Britain is concerned, Mr. Hewitt considers that its production is not likely to be increased. This conclusion he bases on two facts, the first being that during the past ten years the production of this country has practically remained stationary, and the second, the increasing dependence of its iron and steel trades upon foreign supplies of ore. These are two indisputable facts, but, notwithstanding, it is generally believed in this country that the production has been limited by the demand, and not that the demand has had to seek in other quarters for its fulfilment, owing to our inability to satisfy it. Mr. Hewitt estimates that by the end of the present century the United States will be called upon to produce some 15,000,000 tons of pig iron, on about double its present production. Its capacity to do this he does not doubt, and the data upon which he bases his conclusion are clearly set forth in his address. The authority with which it is his prerogative to speak, is sufficient warrant for respecting his opinion. As regards the possession of the fuel and ore, and the facilities for bringing them together economically, and also with respect to the necessary capital, labour, and skill, Mr. Hewitt speaks most confidently, and as a matter of fact, he considers that the world will have to look to the United States for the means of satisfying, in a very large measure, its future requirements of iron and steel.

For several years past, we have occasionally heard of devices for discharging from heavy ordnance, shells carrying a bursting charge of dynamite or other high explosive. Of course there is great risk attending this, inasmuch as the blow imparted to the shell by the explosion of the propelling charge of gunpowder might cause the premature explosion of the bursting charge in the shell, for dynamite can be, and is, exploded by concussion. Lieut. James W. Graydon of the U.S. Navy is among the workers in the endeavour to render this operation safe. He has designed a gun for throwing dynamite shells, and one has just been completed in this country, whither Lieut. Graydon has come to introduce the system to our Government. In this system the bursting charge of dynamite is made up in small pellets, and placed in a shell, the true flight of which is secured by a tapering telescopic tail. The gun is to be discharged by the expansion of compressed air at a pressure of 5000 lb. per square inch, the impulse of which is a safer propelling energy than the ignition of powder, because it does not operate so suddenly as to cause a danger of the premature explosion of the shell. The gun has a calibre of 15 inches, and is to throw a charge of 600 lbs. of dynamite a distance of 3 miles. The barrel, which is 30 feet long, is of Whitworth forged steel, and the breech is closed by means of a steel screw-block with interrupted threads. The projectile with its bursting charge weighs 1300 lbs., and is loaded into the gun by hydraulic apparatus. There are thirty-two compressed air reservoirs, each 4 feet high and 10 inches diameter. They are placed on the gun carriage in four sections of eight each, two sections being on either side of the gun. Fitted with air compressed to 5000 lbs. per square inch, or about $\frac{1}{340}$th of its original volume, the capacity of each at the working pressure is 17,000 cubic feet of air, weighing 11 cwt. in its compressed condition. Any number out of the four sections may be discharged, according to the range desired or the weight of the projectile. The discharging valves are a special arrangement of the piston type, and are packed on the hydraulic system. The carriage is supported on a roller path 21 feet in diameter, having conical rollers geared together, and actuated by a small high-speed engine driven by compressed air. The gun will give an all-round discharge, and can be loaded, elevated, trained and discharged by one person. The gun has just been finished, having been manufactured by Messrs. Taunton, Delweard, Lane & Co., of Birmingham, and is shortly to be tried by our Government. The results of the trials will doubtless be looked for with interest, as being likely to indicate the direction of a new and important development in warfare.

Turning from the arts of war to those of peace in connection with the use of explosives, I may here notice the addition of an explosive signalling apparatus at the Bell Rock Lighthouse. This lighthouse is supplied, as it has ever been since its erection, with two large bells, which are rung during foggy weather. The bells are still to be used, but it has been thought that a fog signal may also be useful, both from the report and the flash of the explosion. The prominent feature of the apparatus now being used is a rod, bent into a large hook at its upper end, which rises to a height of 18 feet above the lantern of the lighthouse, and is covered with insulated wire. The rod is attached with a worm screw to a revolving shaft inside the lantern, and when it is desired to charge it, the rod is brought down by working a fly-wheel with manual power. The hook end of the rod, by the working of the wheel, bends over and reaches the balcony, where it is charged with an explosive cartridge, and a detonator, and is fired by means of an electric spark. It is the first explosive signal that has been introduced into the lighthouse service in Scotland.

It is satisfactory to be able to record that one of the most important of recent engineering projects was successfully completed during the past year. I allude to that magnificent structure the Forth Bridge which was opened for traffic last spring. The conception and construction of that bridge has become a matter of history, while the bridge itself stands as a monument of the constructive talent of two of our honorary members, Sir John Fowler and Sir Benjamin Baker, not forgetting the remarkable power of resource manifested by Sir J. Arrol during its erection. It is also equally satisfactory to know that the construction of another important scheme, the Manchester Ship Canal, is being successfully pursued and is drawing attention to the feasibility of such schemes in other directions.

The subject of canal transport reminds me that efforts are now being made to resuscitate the Panama Canal scheme, and at the same time the rival scheme, the Nicaragua Canal, has secured sufficient favour to attract a large amount of capital, which has nearly all been expended, and the promoters are now applying to the United States Congress for national support.

The water-borne ship railway is a project which attracted some attention in the early part of last year. It is the invention of Mr. W. Smith, the harbour engineer of Aberdeen, who seeks to overcome many of the grave defects inherent in previous similar schemes by making the vessel water-borne in the cradle of the railway. This he proposes to accomplish by supporting and cushioning the ship in the cradle with elastic reservoirs of water.

The last, but by no means the least interesting matter in the present connection that I shall bring under your notice is the Elmore process of manufacturing copper tubes and cylinders direct by electrical deposition. Until within the last few days the process has been kept quite private, but it has now been made public. Some years since Messrs. Elmore invented their system of electro-deposition on a large scale, which has been adopted in some of our leading copper works, the metal thus produced being perfectly pure. The next step was to deposit the copper in the form of the articles required to be made from it, and this is now being done on a commercial working scale at the Elmore works, near Leeds. The bar copper is first melted and poured into water to granulate it, the granulated metal being placed in the bottom of the depositing tank. The manufacture is at present confined to tubes, cylinders, and similar articles, and the copper is deposited upon a cast-iron mandrel which is slowly revolved in a bath of sulphate of copper in the tank through which a current of electricity is conducted. The copper is rendered dense, fibrous, and cohesive, by means of an agate burnisher, which slowly travels under pressure, to and fro, over the surface of the copper as it is deposited. The rate of deposition is one-eighth of an inch per week, and when the required thickness has been attained, the mandrel with its copper coating is removed and put in a machine, where it is again slowly revolved. A small friction roller is then brought to bear upon it, and is made to travel over the face of the copper from end to end in the same way that the burnisher does, but under greater pressure. The travel of the roller over a 12-foot length of 9-inch tube is completed in about half an hour, when it is found that the tube can be easily slipped from off the mandrel. This is due to the circumstance that an expansion of the metal has been produced, so that the internal diameter of the tube is larger than the external diameter of the mandrel. The increase, however, is really only infinitesimal, as has been shown by calipering; but it is just sufficient to allow the tube to slip from off the mandrel. The copper thus produced is very pure, and of high tenacity, the ordinary standard quality showing a tensile strength of 20·8 tons per square inch, with 21 per cent. of elongation. The harder kinds give much higher results, Professor Unwin having tested some samples which gave respectively 39·29 tons, and 41·28 tons per square inch. The conductivity of wire made from this copper is also found to be

102 per cent. of Matheson's standard, as against 98 and 99 per cent. with ordinary copper wire. The interest of the process lies in the fact that by it, finished copper articles are automatically produced direct during the process of electro-deposition. It moreover constitutes an interesting addition to our stock of knowledge as regards electro-metallurgy, and appears to be a practical success.

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And now, gentlemen, the flight of time warns me that I have detained you sufficiently long, I trust not too long, while I have passed in review before you some of the more recent advances in the arts and sciences, and in their practical application to the requirements of everyday life. I am but too well aware that more, very much more, might have been said upon any one of the subjects on which I have touched in a but cursory manner. I am aware, too, that I might have greatly added to the number of those subjects, but I do not think my abstention from so doing will be regarded by you as a fault on the wrong side. Each of us in our professional work, or reading, must become more or less familiar with what is going on around us; and even were I to exhaust my list of subjects, one or other of you would probably be able to suggest others yet untouched. And with regard to the further expansion of the subjects I have already touched upon, my words might have but little effect upon tired ears. What I have preferred to do is to bring before you a plain statement of facts concerning matters in which we all of us take a more or less direct practical interest, and in some cases to express my own opinion upon them. One cannot hope in an inaugural address to give much that is of practical value to others, nor indeed is one expected to do so. The best that can be done is to embody such information as in the present may prove interesting, and in the future not be wholly worthless, as a landmark of to-day. The developments of science are so many, and they follow on each other in such quick succession, that the idea of yesterday is the fact of to-day, while to-morrow it will have become mere history. Thus it may be that each fact that I have brought before you to-night will, before the year is out, have become transformed into a stepping stone, upon which another advance shall have reared itself. So let it be, for this is progress, and progress means a higher development of intelligence, a higher standard of mental culture, and a higher condition of physical, and, I trust, of moral excellence. What matter if our cherished ideas, our well formulated schemes, our important discoveries, do become mere historic atoms, do form stepping stones for the advances of others? So long as the attendant circumstances of life move in their present course, and so long as the conditions of existence remain the same, science will not stand still. Let us therefore accept the inevitable, and let us one and all do our best to help in building up history, be our contribution ever so small. Our names may not all be engraven on the keystone of progress; they may, however, have an imprint on one or other of the voussoirs of its great arch.

March 2nd, 1891.

W. N. COLAM, PRESIDENT, IN THE CHAIR.

THE BALANCING OF HIGH-SPEED STEAM ENGINES.

By ARTHUR RIGG, PAST-PRESIDENT.

ON the 5th of April, 1886, the author read a paper before this Society on "Obscure Influences of Reciprocation in High-speed Engines." That paper treated, somewhat exhaustively, of those effects of reciprocation which are first met by the compression of exhaust vapours or other means, and by which their operation becomes so softened as to minimise any injurious effect on the engine itself. This earlier paper also investigated the limits of speed beyond which these strains became excessive, and described a graphic method by which calculations might be made for any given engine to ascertain their duration and incidence. It is intended in the present paper to carry the subject further by considering the methods employed for balancing or neutralising these stresses so far as they appear outside the engine itself, and make themselves evident by causing tremor or vibration to foundations or adjoining buildings.

It is well known that the effect of reciprocation at either end of a stroke is exactly the same as if all the parts which reciprocate were concentrated around the crank-pin, so the centrifugal force at that point forms a measure of the resistance to be overcome by steam pressure in acceleration of the piston; or given out as it completes a stroke. This centrifugal force can be calculated by the following formula:—

$$\text{Centrifugal force F} = \text{weight in pounds} \times \text{radius in feet} \times (\text{revolutions per minute})^2 \times \cdot 000341.$$

and the exact pressure curve as modified by the length of the connecting rod can be ascertained by methods explained in books on the steam engine. Fig. 1 gives a graphic representation of the forces which are due to reciprocation. The influence of a long connecting rod in modifying their incidence, increasing them at the commencement of a forward stroke and diminishing them at the commencement of a return stroke, and the ratio of increase or diminution is :—

$$\frac{\pm \text{ Mean acceleration pressure} \times \text{length of crank}}{\text{length of connecting rod.}}$$

HORIZONTAL HIGH-SPEED ENGINES.

Taking as an example the American Porter-Allen type with a 12-inch cylinder, and 24-inch stroke, we find it making 200 revolutions per minute, and that all its reciprocating parts weigh 470 lbs. The centrifugal force developed at each end of a stroke is equal to a mean pressure of 6410 lbs., or nearly 3 tons, and this is repeated 400 times a minute.

$$\text{The ratio } \frac{\text{crank}}{\text{connecting rod}} = \frac{1}{6 \cdot 16};$$

so it is necessary to add $\frac{1}{6 \cdot 16}$ or 1040 lbs. at the commencement of a forward stroke, and to deduct a like amount at the commencement of each return stroke. Thus the actual pressures to be resisted by compression or otherwise, as the piston approaches the crank will be :

$$6410 - 1040 = 5370 \text{ lbs., or } 47 \cdot 5 \text{ lbs. per square inch,}$$

and as it returns

$$6410 + 1040 = 7450 \text{ lbs., or } 66 \text{ lbs. per square inch,}$$

and the same figures will measure the steam pressure absorbed in giving motion to the piston, &c., given out on its return stroke. These forces are transmitted directly to the crank as a blow, when no cushioning is provided ; or else to the cylinder covers when the exhaust compression has been accurately proportioned. In every case, however, they ultimately reach the engine bed, and are transmitted through it to the foundation, and absorbed therein exactly in the same way as the blow of a steam hammer is absorbed by its massive foundation.

With vertical engines this analogy is complete, and in this type it is only necessary to provide that the crank shall be balanced with sufficient margin to resist the horizontal component of the connecting rod's angular movement. All purely vertical strains are transmitted directly to, and resisted by the foundation, in the case of a single crank engine, but where there are two or more cranks each has an effect on the other's work, which may partially or wholly prevent their combined action from appearing outside. The case of a horizontal engine, however, is altogether different—

If A, Fig. 2, represents the concentrated weight of reciprocating parts, and B a balance weight equal and opposite, it will be seen that at each end of a stroke the centrifugal force of A in the direction of the lower arrow will be exactly equal to that of B in the direction of the upper arrow, and a perfect balance would ensue for a moment, but when A arrives at C its acceleration is completed and no balance is required, although B has reached D and is exerting its full pressure downwards. All therefore, that has been done is to translate the horizontal into a vertical strain, and no visible advantage accrues thereby. If, however, the weight at B is constructed so as to amount to about half of the concentrated weight of piston and motion block, adding the outer end of the connecting-rod, the effect will be to transfer about half of the stresses from a horizontal into a vertical direction, where they are resisted by the mass of foundation, and the engine will run with increased smoothness, and be balanced in a manner as good as can be secured by this compromise. This arrangement is carried out in the horizontal engine shewn by Fig. 3, which represents the elevation of an engine made by the author in 1880.

This engine is very similar to the well known Armington-Sims type. It has cylindrical valves with a rate of expansion determined by the governor. The cylinder is 14 inches diameter, 21 inches stroke; and the engine is driven at 154 revolutions per minute by steam of 115 lbs. pressure per square inch. This comparatively small engine has for the last eleven years been in regular hard work, performing from 80 to 100 indicated horse-power, and working with remarkable economy, both as regards fuel and repairs, the cost of the latter being scarcely anything.

Here the balancing of the reciprocating parts has been most carefully proportioned to the speed of running, and this is accomplished, partly by the careful adjustment of the exhaust compression, and partly by a weight behind the crank, so that the horizontal stresses are in a sufficient degree changed into vertical ones. The engine bed is exceptionally stiff and heavy, yielding a great advantage, neglected too much now-a-days, and for obtaining a moderately increased speed with economical results in fuel, this class of engine possesses many advantages. This particular example was running for some time at 200 revolutions during the night time, and 150 to 160 revolutions during the day, to suit different classes of machinery, and no difficulty was ever experienced in maintaining the higher speed.

So many novelties in engine construction have been introduced within the last ten years, that it has seemed to the author well-spent time to call to remembrance this class of high-speed horizontal engine much used in America, and here also to a more limited extent—though not as much as it deserves to be.

Perhaps this may be in some degree because of the small space which so many owners and architects allow for engineer's work. Both seem to think that any hole or corner is good enough for a steam engine! Moreover, this is a class of engine which does not receive much attention from the somewhat academical engineering of the present day, but it is one which for the moderately increased speed seems well able to uphold its reputation against all comers.

Single-acting Engines.

Perhaps no feature in the modern high-speed engine practice is more conspicuous than a frequent return to single-acting cylinders; it is argued that as the steam pressure acts in one direction only, it becomes easier to run an engine of this class quietly, because the crank is not subjected to the alternating strains due to the reversal of pressures as in double-acting cylinders. The strains produced by reciprocation remain exactly alike, whether the steam acts on one or on both sides of the piston, so that the question of external balance must be considered quite apart from this peculiarity of modern steam engine construction.

Much attention has been devoted to the arrangement of two, and sometimes three, engines in a line with cranks opposite each other for two-crank engines, or at 120° for three-crank engines, and in all these it is intended that the strains developed by each engine shall be more or less accurately balanced by those on the other, or others. Such a balance in the simple case of two engines, to be accurate, involves the condition that one cylinder shall be exactly opposite to the other, and some engineers have considered this feature so important that they have constructed engines to embody it, but this refinement scarcely appears to possess sufficient practical value to compensate for its additional complexity.

When a pair of cylinders are placed alongside and close together, with their cranks opposite, the balance is considered good enough for all practical requirements; and it is only necessary to guard against a tendency to rock on the foundation in consequence of the "couple" induced by the balance acting in different planes.

Of this class of steam-engine none surpasses those made by Messrs. Willans and Robinson; the strains have been worked out in the most careful manner, and these engines present so many examples of the practical application of sound theory that an entire evening might well be devoted to their consideration. At present, however, the question is as to the arrangement by which two engines are fixed on the same bed with cranks opposite, and the strains on one of them balance more or less equally the strains on the other; attention must also be drawn to the singularly effective method by which the heavier terminal strains are received by an air buffer instead of by exhaust compression, and thus find their way to the engine framing and foundation.

Through the kindness of Mr. P. Willans, the author is enabled to give a diagram (Fig. 4) of the curves due to reciprocation and the air cushion respectively—both plotted out to the same scale. Instead of an exhaust compression being employed to bring the pistons to rest at the termination of an up-stroke, or steam pressure being absorbed in starting them on their downward course after the crank has turned its centre, there is provided an air buffer developed out of the ordinary guide bar. This independent cylinder is made of such dimensions, and is provided with such clearance space as to give a compression curve running nearly on a line with the inertia curve produced by the moving parts at their normal speed during their upward stroke. This example is taken from a compound engine with steam cylinders of 20 inches and 14 inches diameter × 9 inches stroke, which developes 200 horse-power at 350 revolutions per minute.

The guide piston or air buffer has an effective area of 125·7 square inches. The weight of the moving parts is 430 lbs., and the acceleration curves calculated for 395 revolutions per minute is shown in the diagram (Fig. 4.) The connecting rod is very short in comparison with other classes of engines, and

$$\text{The ratio } \frac{\text{crank}}{\text{connecting rod}} = \frac{1}{4\cdot72}.$$

The mean terminal pressure due to reciprocation is 8578 lbs., and to this must be added $\frac{1}{4\cdot75}$ or 1815 lbs. for the termination of the up-stroke or the commencement of the down-stroke, and the same amount has to be deducted for the commencement of the up-stroke. These forces are: for the upper end of a stroke, 10,493 lbs., for the lower end of a stroke, 6763 lbs.

The corresponding pressures per square inch on the air buffer cylinder will be: for upper end of stroke = 83 lbs. per square inch; and for lower end of stroke = 53 lbs. per square inch.

The acceleration curve is illustrated by P. T. Fig. 4, and the air compression by R. S. This has been so arranged to touch, but never to exceed in pressure the acceleration curve. By this arrangement the air buffer acts exactly like a spring; it absorbs energy from the ascending piston, and that energy drives it down again during the return stroke without any loss.

The double base lines in the diagram are for the addition or subtraction of the weight of the piston rod, which is added to the down-stroke and deducted from the up-stroke, the engine being vertical. This arrangement in no way interferes with the regulation of steam exhaust compression or steam inlet, both of which need to be considered in ordinary engines where exhaust compression is usually carried far enough to overcome the inertia of the moving parts; and steam pressure must be expended in starting the piston on its downward path. It does not seem generally noticed that these operations become sources of permanent loss that cannot be recovered, and they are doubtless in some degree answerable for the generally uneconomical reputation which so many high-speed engines possess, but this source of loss is altogether absent in the engines now under consideration. In ordinary high-speed engines, locomotives for example, it is usual to provide capacious ports for the purpose of securing a compression curve which shall be a sufficient approximation to the inertia curve, as this would not be brought about were short or contracted ports used.

By the employment of an air buffer, the dimensions of ports can be settled purely with reference to the cylinders and steam inlet, which can thus be made of the most suitable proportions; without being interfered with by the necessity for considering a convenient exhaust compression. Thus all considerations belonging to the stopping or starting the reciprocating parts in Mr. Willan's engine are transferred from the steam cylinder to the air buffer, and its capacity can be regulated by calculation or with the assistance of an indicator, so as to give any desired curve of compression, and the steam ports are made exceptionally short and of small capacity in proportion to the cylinders, thus gaining the well-known economy resulting from such proportions. For the lower end of each stroke no provision is made to cushion the impact due to reciprocation, so that it falls entirely on the crank, and thus it receives the entire impact of the lower stroke amounting to 6763 lbs. which it resists without further provision.

So many advantages have been gained by the use of an air buffer for the upstroke that it almost seems as if it would be a good thing to employ the same system if only partially for the downstroke end. In vertical engines placed alongside with their cranks opposite, there is a general reduction of strains as compared with those produced by a single vertical engine, but there remains always a certain irregularity caused by the difference between the upper and lower strains as influenced by the connecting rod, and also a "couple" or rocking motion. These varying strains are clearly shown by diagram (Fig. 5), where Y. Z. represents the distance between two cylinders, and while P Y and P′Z are the acceleration measurements for the upper portions of the stroke Y Q′ and Z Q are corresponding pressures for the lower end of the stroke. Thus it will be seen that there is an irregularity of no practical consequence in the balance, besides a general tendency to rock as already mentioned, but both of these are absorbed by the foundation.

THE BALANCING OF LOCOMOTIVE ENGINES.

Reciprocation in locomotive engines becomes converted into variable velocity, on account of the piston being carried along at a greater rate of speed than its own proper velocity, and thus the balancing question assumes a different aspect compared with the case of stationary engines, where the piston comes to a state of absolute rest twice during a revolution. In a locomotive this zero corresponds with the distance travelled, and a relative movement takes place, so far as reciprocation is concerned, instead of the absolute conditions under which a stationary engine works. Then the balance weight, fixed in one of the driving wheels, although always possessing a circular movement in relation to the cylinder is subjected to a forward velocity, variable according to its radius, from a state of momentary rest to double the mean velocity, and with so many complications it is no wonder that locomotives are balanced by experiment, rather than by any elaborate calculations.

REVOLVING ENGINES.

With all reciprocating engines it is necessary to provide for the impact of moving parts; and as speeds increase and powers enlarge, so a limit is reached beyond which the endurance of materials cannot be strained. There can be little doubt that much of the difficulty attending the introduction of higher speeds has been due to an insufficient appreciation of the magnitude of those forces, and it therefore seems desirable, if possible, to find a solution to the problem, how to do away with the cause which at present sets a limit to the power and speed of reciprocating steam engines; while still retaining the use and advantages of pistons and cylinders. So much skill, time, and capital have been expended upon rotary engines without any marked success, that all the avenues in this direction seem closed, but the revolving cylinder type presents peculiar advantages. This is a system of cylinders and pistons, both of ordinary construction, and provided with the well-known self-regulator packing rings: instead of the cylinders being fixed they revolve simultaneously with their several pistons around separate and distinct centres. The distance apart or eccentricity of these centres is a measure of half the stroke, and is in fact, a crank to the system, and this description of engine seems to be a half-forgotten type, first invented and made a subject of experiment during the early years of the present century.

It has occasionally been re-discovered, and always possessed a singular fascination from its extreme simplicity and the beauty of movement by which the reciprocation of a piston is converted into rotation without the employment of an ordinary crank. The diagram Fig. 6, will serve to explain the arrangement. A number of cylinders are arranged to revolve round a centre E, while corresponding pistons revolve round the centre O, there being consequently an eccentricity equal to E.O. At the position 1 A the cylinder and piston-circles coincide, and at 5 B they are farthest apart. During the travel from A to B there is a gradual increase 2 *c*, 3 *d*, 4 *e*, to 5 *f*, and as the movement continues there is a decrease in distance to 6 *g*, 7 *h*, 8 *k*, until at 1 A the circles again coincide. These positions correspond with movements of each piston in its cylinder, and the general mechanical arrangement of this engine is shown by Figs. 7 and 8 giving a general front section and side section of the author's arrangement of this engine. These show how the three cylinders and three pistons are arranged to revolve around their respective centres; the cylinders are balanced against each other during construction and also the pistons. Thus each opposite cylinder and piston forms a distinct independent balanced system, and although these pistons and cylinders possess a sliding movement each as regards the other, yet there is no reciprocation in relation to the framing or foundation, and consequently it might be supposed that an absolute theoretically perfect balance has thereby been secured.

This, however, is not quite the case, inasmuch as there is an acceleration and retardation in respect of angular movement, and a constant though small change in the position of the mean centre of gravity of the entire revolving mass. These changes are infinitesimal in comparison with the totals produced by other types, and are easily absorbed by the foundations, if the engine has been accurately balanced during construction. The result is a practical elimination of all reciprocating strains, and the substitution for them of a varying velocity, which should not cause vibration.

Assuming a constant mean speed of the fly-wheel, it follows that as the pistons move outwardly in their respective cylinders, as from 1 A to 5 *f* (Fig. 6.) their mean velocity decreases, but as the pistons return from 5 *f* to 1 A their velocity increases. These changes naturally have an influence upon the cylinders, tending to wear them oval, but this is easily counteracted by providing sufficient guiding surface. Moreover, they do not affect the regularity of motion, because as one set of cylinders and pistons become drivers, in so far as their velocity diminishes, so another opposite pair become drivers in an equal degree, and these internal forces mutually counteract one another, and do not appear outside.

To explain more fully the general construction of this engine it may be observed, in relation to the front view, Fig. 7, and the vertical side section, Fig. 8, that each cylinder has a boss cast upon it to clasp the main bearing stud, around which all the cylinders revolve; thus each has a free independent circular motion, and retains a direct line for pressure between the central stud and the crank pin projecting from the face of the fly-wheel. In the boss belonging to that cylinder nearest to the valve face, called No. 1, there are three ports, one leading to each cylinder through intervening bosses, and as these turn round they successively present themselves in front of the steam inlet and the exhaust. According to the direction in which the engine has to run, so is the steam inlet placed to the right or left; and this arrangement facilitates the construction of these engines for reversal and variation in the rate of expansion in whichever direction they turn round. In the minor details of this engine, differing so widely as it does from other types, it may easily be supposed that peculiar difficulties have been encountered. Among these may be mentioned lubrication, which gave much trouble, and has finally been secured by the application of a pump forcing a small but regular supply of oil between the central stud and the cylinders, so that they revolve freely and without unnecessary friction. This friction is regulated by the self-acting adjustment of the cylinder bosses. This is done by a long bolt leading from an enlarged head or piston through the centre of the main stud outside to the front of the valve chest. Lock nuts are used for a preliminary adjustment, and this is supplemented by the admission of steam behind the enlarged head of this bolt. This is, in fact, a piston with ordinary packing rings, and thus the elastic steam pressure keeps the several faces together sufficiently to prevent needless friction, and yet permits the whole to turn freely. These practical details have been obvious from the very first, and are well within the competence of any engineer who is familiar with the necessities of high-speed engines, and need not be pursued further, as perhaps they scarcely enter into the special subject of the present paper. Summarising the various methods of balancing high-speed engines, the following conclusions are arrived at, viz. it would appear that there are three general systems by which the outside strains produced by steam engines can be met:—

1. By a direct balance weight opposite a crank, as in ordinary horizontal engines, transforming part of the horizontal strains into vertical ones.

2. By setting two engines alongside with opposite cranks, so that the strains produced by one counterbalance those produced by the other.

3. By doing away with reciprocating strains altogether, as in the revolving cylinder type.

The first-named system of balancing is good up to a moderate increase upon ordinary speeds, and may be used for engines of very considerable powers with economy, endurance, and success. But it is very surprising to notice how many steam engines there are of the horizontal class where no proper balance has been attempted, although their owners seemed to have spared no expense in other ways for securing every advantage that money can purchase. Indeed, it is by no means easy to understand why so well known and simple a provision as that of a proper balance weight should have been overlooked either by the owners or engineers.

The second system of balancing is more self-contained; it allows a considerable increase in speed, and is effectual for engines of moderate power running at speeds suitable for driving dynamos and such work. Thus it marks an advance upon the balance weight in a simple engine, and reaches what seems to be a limit to the speed of reciprocating steam engines, so far as this is connected with the dynamic influences of their reciprocating parts.

The third system, by which the effects of reciprocation may be altogether evaded, promises in its turn to enlarge the limiting influences as to speed from dynamic relationships of the reciprocating parts to others connected with centrifugal force of the whole engine, and with the admission or efflux of steam through the passages in connection with the cylinders. Thus the limit of speeds which may be safely entertained becomes advanced to a stage beyond which it is difficult to foreshadow anything further while using pistons and cylinders; and even if this system does no more than render less severe the present strains on the highest speeds of reciprocating engines, it marks a gain of no little value.

This paper is restricted to a general view of one particular feature of modern high-speed engines; it may also suggest that, although the present is that which most concerns the engineer, yet the practice of ten or fifteen years ago possesses much of real interest and considerable value, and that it is well also to look forward and pay some attention to those changes which may still be waiting notice in the future.

DISCUSSION.

The PRESIDENT, in proposing a vote of thanks to Mr. Rigg for his interesting and valuable paper, said that the subject was one which now required the attention of most engineers. In many works at the present time most elaborate experiments were being made to ascertain what Mr. Rigg had been trying to explain in his paper. All high-speed engines and gas engines required this question to be solved, and a great deal of money had been spent in endeavouring to ascertain the most efficient arrangement. Mr. Rigg had made a study of this subject for many years, and the present paper was really only the completion of a paper which he laid before the Society a long time ago. He expected a very good discussion, and he considered that Mr. Rigg deserved the very hearty thanks of the Society for giving them the results of a vast amount of labour and expense.

Mr. RIGG acknowledged the thanks of the Society, and remarked that the subject, when he first paid attention to it, was one with which very few were acquainted; but now it was very common to find people who professed to know everything about it, and it was very curious to meet with such a change.

Mr. AMBROSE MYALL said that he wished to thank the Secretary for the kind invitation, which had enabled him to have the great pleasure of hearing the able paper of Mr. Rigg. He was afraid that it would be rash on his part to attempt the addition of anything to what they had heard. Mr. Rigg's name was intimately associated with this class of work, and probably there was no one so thoroughly acquainted with the subject of the balancing of engines. If he remembered rightly, he saw a considerable time ago a communication in an engineering paper from Mr. Rigg, the mention of which might be of interest. In this communication a special kind of connecting rod was shown. The form of that connecting rod was such, that its centre of gravity would always coincide with the centre of the crank pin, so that an equal counter-weight on the crank-shaft or fly-wheel would always exactly balance the connecting-rod. He did not know that this was altogether a practical arrangement. If carried out, it would make a very clumsy form of connecting-rod; theoretically it would entirely eliminate all strain due to the motion of the connecting-rod, but would not affect the strain due to the motion of the piston and piston rod.

Mr. CROHN said that it was of vital importance to the firm which he represented to know what was going on. They had been trying a large number of experiments, and were still doing so, but he did not know that he could say much on this particular paper except that with triple-expansion engines and three cranks at equal angles, and also with quadruple expansion engines, they got a very good balance, even without the use of balance weights on the cranks.

Mr. H. ROUNTHWAITE said that he had not found it necessary to do anything more than keep the pistons and other reciprocating parts as light as possible. His work had been mostly triple-expansion engines—three cylinders working on three cranks. The pistons were usually single discs of cast steel of a coned or dished form. He was alluding to engines with low-pressure cylinders of from 40 inches to 50 inches diameter, and strokes of 18 inches to 21 inches, running at from 300 to 380 revolutions. He was a little bit anxious about them at first, and he thought that they might give trouble, but he was glad to say that there had been usually no trouble whatever. He had had some diagrams prepared from the indicator cards, &c., showing what the various pressures in the engines really were, but he believed that these results were to be communicated to another society at an early date, so that it would be hardly fair for him to give any more detailed information about them.

With smaller engines, such as those for driving dynamos direct, say two-cylinder compounds about 8 inches and 12 inches by 8 inches stroke with two cranks, very steady running was obtained by placing cranks opposite one another, without any balance weights, the reciprocating parts being of course kept as light as possible.

Mr. DUNBAN said that Mr. Rigg's name had been a familiar one to him for the last 30 years: He did not think that any person could differ from the statements which Mr. Rigg had made.

Mr. W. T. LORD said that he spoke with very great diffidence as he was a mere infant in practical mechanics. His acquaintance with it originated in joining an engineering company, in which he put a great deal of money, with the main purpose of manufacturing a patent high-speed engine, with the not unusual result of having lost it, owing to the absence of the very quality about which Mr. Rigg had been speaking. The engine, to which he had been induced to pin his faith, wasted fully 75 per cent of its energy through the lack of balance, and by lateral stress. Upon the advice of an eminent member of the profession he supplemented the amount which he had first invested by about another thousand, and that went the same way. He then, greatly to the annoyance of the patentee, ventured to make some experiments of his own, which conclusively proved the case, and therefore he designed some alterations, which removed the stress due to lack of balance, and gave, approximately, the efficiency which the engine should possess. The engines, with which he was more particularly acquainted, were those which had to do with electric lighting. He had brought with him a sectional working model of an engine which he had in use on the Midland Railway for train lighting. It was a three cylinder engine, in which the cranks being placed at an angle of 120°, the stresses which were so disadvantageous in some engines were nearly eliminated. He had recently seen a little balanced engine at Messrs. Easton and Anderson's, and one of the directors, Mr. Wilson, had assured him that in consequence of the very perfect balance in that engine, a higher percentage of efficiency was attained than could be got with an unbalanced engine, having similar cylinders, placed in the usual manner, but the misfortune was that being made, as Mr. Rigg had mentioned, with opposite cylinders, it became a costly thing, because the making of it was almost equivalent to the making of two engines He thoroughly concurred with nearly all that had been said by Mr. Rigg, but he took exception to the statement that his rotating engine eliminated all the stresses. The centre moved continuously, but still it was equivalent to the moving of an eccentric only, and he could not see how the moving to and fro could eliminate the unbalanced stress which Mr. Rigg spoke of. Perhaps Mr. Rigg could enlighten them upon that point. There was a reciprocating movement which wanted balance, for, after all, that engine was only a single-acting engine.

Mr. J. W. Wilson said that he had not been able to gather from Mr. Rigg's very valuable paper whether he approved, or otherwise, from the point of view of the subject before them, of an engine with cylinders placed at right angles. That might not be a commendable arrangement in ordinary high-speed engines, but occasionally there were cases to be met with in which for special reasons such an arrangement appeared to be preferable; as for instance, the possibility of a consequent simplification of valve gear. He thought they must all feel that Mr. Rigg's paper had been of great interest: the only matter of regret being that it had not been longer.

Mr. Rounthwaite suggested that it would be interesting if Mr. Rigg would oblige the meeting by giving them some particulars as to the extent to which his engine had been introduced, and the purposes to which it had been applied, with the general results obtained.

The President explained that Mr. Rigg, in order to oblige the Society, had prepared his paper much earlier than he expected to have to do. He thought that Mr. Rigg had done very well, considering the short time which he had had at his disposal.

Mr. Rigg, in replying to the discussion, said that he was much obliged for the President's explanation. If he had had more time he should have made the paper longer, and entered upon other sorts of engines, particularly locomotives. The balancing of a locomotive was a very curious thing, because the conditions under which reciprocations occurred while such an engine was running, differed totally from those to be observed, while the engine was raised off the line and so standing at rest, under the conditions of an ordinary fixed engine. In the one case the piston partook of the horizontal movement of the locomotive, which was more extensive than its own reciprocation. Thus, when the locomotive was running, these reciprocations were really no more than variations in horizontal velocity; whereas when the same engine was fixed, the reciprocations caused a far more extensive series of strains, inasmuch as a change from rest to motion is necessarily greater than any mere variation in velocity. Mr. Myall had kindly given him credit for inventing a connecting rod, but that rod must have been made by somebody else, for he, Mr. Rigg, really did not know anything about it. The next speaker, Mr. Crohn, said that he was trying experiments, and such experiments were very good things, but he thought, after all, the safest course was to make calculations first, and then try experiments, and then make calculations again. To make experiments without knowing the principles upon which they were to proceed would not only be to work in the dark, but also to prolong the time and increase the expense and trouble of the experiments. Another speaker had said that he did not balance his engines, for they had three cylinders, and this agreed with what he, Mr. Rigg, had mentioned in his paper, viz. that three-cylinder engines practically balanced themselves with low-piston speed. In calculating out the lost power in some engines he found that the practical result of balancing by compression of exhaust steam was that the amount of work wasted at different rates of expansion with a single slide valve varied from 5 to 60 per cent. of the total power. This rather agreed with the remark of another speaker who said that he wasted 75 per cent. of the energy with his engines improperly balanced. He had not much difficulty in believing that statement, but all engines wasted a certain amount of work from start to finish. They gradually lost more and more power all the way as rates of expansion varied, and it was only the balance doing useful work that was of any practical good. It was, he believed, the same speaker who asked to what extent his engine was applied. He had intentionally said very little about his own engine so as not to make his paper seem an advertisement, and he merely brought it forward as a case in which the balancing had been effected upon a totally different system from any other kind of engine. To test this point one of these revolving engines had been driven over 2000 revolutions a minute without being bolted down, and he thought that was a good enough test to prove the efficiency of any balancing system. One speaker had suggested that there was a reciprocation in this form of engine. This, however, is not so. There are two independent systems of motion known to mathematicians: one, the relative system where two bodies move in relation to each other, and there was our absolute system, whereby bodies move in relation to the earth. He used the term reciprocation in the latter of these senses, and not in regard to a relative movement. In this particular example all the pistons revolved around one centre, while all the cylinders revolved around another centre. If the pistons were at one end of the room, and the cylinders at the other end of the room, each separate system would be properly balanced within itself, and the fact that one system worked inside the other was no interference with the perfect independent balance of both. Their combined movements did not constitute an absolute reciprocation, but the reciprocation was only relative. The difference between these classes of motion may be illustrated by supposing the balance weight for a locomotive was to be on the rim of the wheel, then when it was on the rail this weight would be at rest, in relation to the earth, but when it arrived at the top it would be going with twice the mean velocity of the rim of the wheel, although during all the time if they looked at it in connection with the movements of locomotive on piston rod, backwards and forwards, then it would appear only as a simple relative motion which would be a pure rotation, without reference to the railway. He did not think that comparison to be a bad illustration of the difference between motions, relative and absolute.

As to the question of balancing large horizontal and beam engines, he had often seen them provided with a plain unbalanced crank of wrought iron or steel, and there was no question whatever that such large engines run better, more smoothly and economically, for having a proper balance weight, than they would have done if they had been left in the crude condition with no balance weight at all. He thought that engineers were apt to forget that although an engine might work slowly, it was still desirable to balance the reciprocating parts.

In the case of a marine engine there was practically no fixed foundation at all; and the balance must be self contained, and therefore marine engines with three cylinders and cranks at 120° possessed a balance of a very perfect character.

The speaker has complained of the paper not going into greater length, and it was quite true that there were an infinite number of ramifications into which the subject might extend, and he should have liked to enter into some of them more fully had time permitted, but it must be remembered that many of the points connected with the subject were dealt with in his previous paper, of which the present paper was practically the supplement and conclusion. He thanked those speakers who had joined him in taking so much interest in the subject; and he thanked his present audience for their attention.

Mr. Crohn explained that in stating in his previous remarks that his firm had been trying experiments, he did not mean to say that they had been doing so without having made calculations beforehand. To do so would have been simply a waste of time. While the experiments were in progress he was not at liberty to say anything about them.

The President said that, perhaps, when the experiments referred to were finished, the Society might have the benefit of them in some form.

Fig. 1.

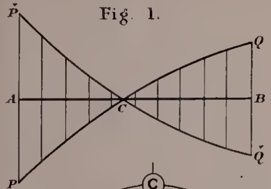


Fig. 4.

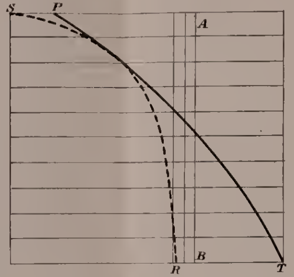


Fig. 5.

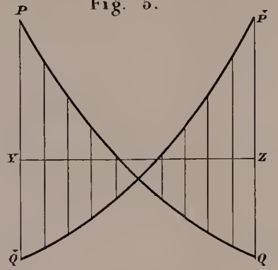


Fig. 6.

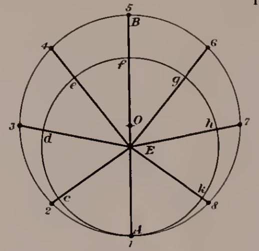


Fig. 2.

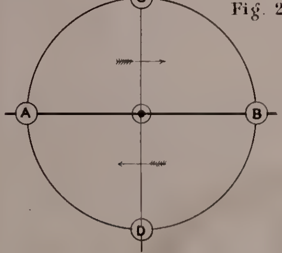


Fig. 3.

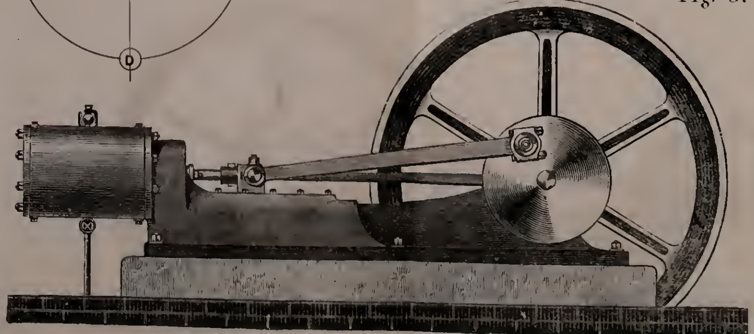


Fig. 7.

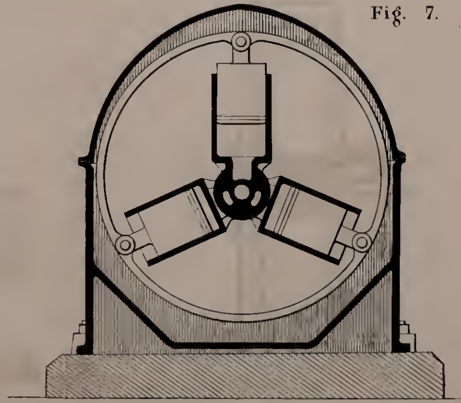
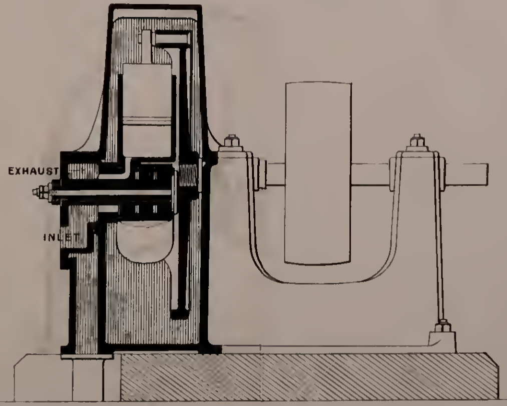


Fig. 8.



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W. N. COLAM, President, in the Chair.

A TRIAL OF A REFRIGERATING MACHINE ON THE LINDE SYSTEM.

By Thomas Bell Lightfoot.

The object of the following paper is to describe and bring before the Members of this Society, the arrangement and construction of a testing station for refrigerating machines, which was lately erected at Munich, by Linde's Ice Machine Company, of Wiesbaden, and the Augsburg Engine Works Company, by agreement with the Committee of the Munich Polytechnic Society, and to give some of the results that were obtained there with a No. V. (12-ton) refrigerating machine on the Linde system.

Owing to the difficulty in obtaining precise and reliable data of the work actually performed by refrigerating apparatus, it was decided to erect a station for the trial of refrigerating machines, and to work it for two years, on the following bases :—

The Committee to undertake the business management of the station and to nominate an Examining Commission consisting of at least seven members. This Examining Commission to have charge of the technical management of the undertaking both as regards the erection of the station and the nature of the experiments to be made. Three members of the Commission to be selected from the teaching-staff of the mechanical division of German Polytechnic High-schools. The chairman to be chosen from the members residing in Munich. The chairman of the Polytechnic Society in Munich, to be a member of the Commission.

Linde's Ice Machine Company, in Wiesbaden, and the Augsburg Engine Works Company, agreed to put at the disposal of the Commission—

A. A piece of land situated in Munich and suitable for the erection of the station, to be selected by the Examining Commission.

B. The necessary means for the erection of the station according to the direction and under the control of the Examining Commission, and consisting of:—

1. An engine-room, containing sufficient space for four complete refrigerating machines of the size mentioned below.

2. A boiler house with two boilers, each sufficient to supply steam for one refrigerating machine, and including the steam pipes.

3. A well, with a steam pump, to supply cooling water for two refrigerating machines, together with all the necessary pipe connections.

C. The means for maintaining the buildings and their fittings, the provision of the salary of the Examining Commission, and generally speaking all necessary for the working of the station during two years, commencing from the day of putting it to work.

After the expiration of two years the station to be returned to the above named firms.

After the nomination and constitution of the Examining Commission and the completion of all the necessary preparatory work, the manufacturers of refrigerating machines were invited to send their machines for trial, and the special programme for testing the machines was drawn up. The programme is generally as follows:—

One representative of each exhibitor is allowed to take part at all the meetings and transactions of the Examining Commission, but has no vote.

Only such refrigerating machines are allowed to be exhibited and tested, as are arranged for cooling brine, and so proportioned as to develop from 200,000 to 240,000 heat units at the most used temperatures in the various industries, and during normal working.

It was afterwards found out that the term "normal working" was interpreted in a sense, which widely differed from the intention under which the programme was drawn up. The Commission, therefore, to avoid further misunderstanding, resolved that by "normal working" is to be understood the working with such number of revolutions, that the machine with a normal refrigerator surface of 712·8 square feet, and when reducing the temperature from 28·4 to 23° Fahr., develops at least 200,000 units. The trials have, therefore, been carried out under the constant number of revolutions thus defined.

All such matters as driving power, shafting, and foundation, are to be provided by the exhibitors. They have also to pay certain fees for testing their machines.

The results ascertained by the Commission are published, and they comprise:—

1. The determination of the efficiency of the refrigerating apparatus.

2. The quantity of steam and cooling water, under conditions equal for all machines of the same kind. In addition, there are included in the reports, so far as the circumstances in the station allow, all the special features of every system, as for instance, the description of apparatus, the change in efficiency with the length of the working time, the losses of the working liquid, the causes of these losses, their influence on the working and on the efficiency of the machines, the lubrication of the stuffing box and other parts, the difference of pressure during the working, as well as the influence of a diminished quantity of cooling water in the condenser, etc., etc.

Experiments are made at the following brine temperatures.*

	At the inlet to Refrigerator.	At the outlet from Refrigerator.
1.	42·8 Fahr.	37·4 Fahr.
2.	28·4 „	23·0 „
3.	14·0 „	8·6 „
4.	0·4 „	5·8 „

The initial temperature of the cooling water is to be 50° Fahr. Four trials with brine temperatures as above are to be made with the normal quantity of water passing through the condenser, and one trial with brine temperatures as in No. 2., but with the quantity of cooling water reduced, so that the outlet temperature from the condenser is 95° Fahr.

The Commission also reserves the right to fix other working conditions by agreement with the exhibitors.

The duration of the trials is the same for every machine, and depends mainly upon the time necessary for the accurate measuring of the feed water. Every trial is repeated under exactly the same conditions, if possible, with a change of the observers.

Only one of the two boilers in the station is used to supply steam to the engines of the refrigerating machines, the other being used for working the engine for pumping the cooling water, and for driving the brine pumps. The consumption of steam for the refrigerating machine is alone determined.

The exhibitor attends to the working of his machine in the engine-room during the trial. The stoking of the boiler and the attendance on the pumps, as well as the regulation of the inlet and outlet temperatures of brine, are controlled by the Commission.

The machines under trial are applied for cooling down a solution of calcium chloride, the freezing point of which is about 8° below zero (Fahr.). The brine is afterwards heated to the desired temperature by means of steam, and returned to the refrigerator.

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* See Table III.

The refrigerating effect is ascertained by obtaining the product of the weight of brine passing through the refrigerator per hour, with the specific heat, and the difference between the inlet and outlet temperatures taken as close as possible to the refrigerator. The weight cooled down per hour is found by measuring the volume, and by ascertaining the specific gravity. The volume is obtained by means of two gauged vessels, one of which is being filled while the other is being emptied. All measurements of temperature are made with special thermometers of great sensitiveness, which are fixed in special fittings provided by the Commission.

Indicators are employed for ascertaining the power exerted by the steam-engine, and in the case of compression machines the power used in compression is ascertained in the same way. The indicator springs are tested in the laboratory for theoretical mechanics in the Polytechnic High School at Munich. The admission pressure of steam into the cylinder is 88 lbs. per square inch above the atmosphere, the boilers being constructed for a working pressure of 117 lbs. per square inch.

The quantity of steam used is ascertained by weighing the feed-water, as afterwards described.

The heat given up to the cooling water per hour in the condenser of the refrigerating machine is ascertained directly from the quantity of the water passing through and its difference of temperature, which is measured as near as possible to the inlet and outlet of the apparatus.

Description of the Station.

The general arrangement of the station is shown in Fig. 1. It comprises a new building, with an older one adjoining, adapted for the purposes of the Commission. The latter is marked A on the diagram, while the rooms B, C, D, E, form the new building.

As will be seen, room is provided for testing four refrigerating machines at the same time, the machinery room, E, being divided by temporary wooden partitions into four compartments, in each of which there is more than sufficient space for the erection of a refrigerating machine No. V. of any system. Each division is lighted by large windows and by skylights.

At one end of each of the four rooms, and running parallel with the boiler-house and engine-room, is a subway about

7 feet wide to receive all the various pipe-lines. Above the subway the condensers and refrigerators of the machines may be placed.

The leading idea in designing the arrangement was to shorten to a minimum the time required for one trial without interfering with its accuracy. The trustworthiness of trials of machines of this kind is mainly dependent on the accuracy with which every part of the apparatus is brought into the same condition at the end of the trial as it was at the beginning. It is most essential especially that the quantity of heat in all parts is the same at the beginning and at the end, in order to be certain that all the cold measured during the trial is really produced in the time, and not taken partly from the cold stored in the machine or *vice versâ.* It is clear that an ice-generator which contains in the moulds a mixture of water and ice offers insurmountable difficulties for the precise determination of the actual refrigerating effect produced in a given time.

It is quite different with brine. It is only necessary to measure the inlet and outlet temperatures of a certain quantity of continuously circulating brine, the physical properties of which are known, and the heat abstraction is at once absolutely ascertained. In normal working, indeed, a very short time is sufficient for the thermal measurement of a machine, by cooling down a quantity of brine which is circulating through the refrigerator, and is again heated on the other side.

Refrigerator measurements, however, form only one part of the experiments. The heat used in the motor is also determined, both by measuring the water passed through the boiler and in other ways afterwards described.

The arrangement of the boiler-house is as follows:—

There are two boilers, one of which is used for the refrigerating machine proper, and the other for working the engine for driving the cooling water and other pumps. With the latter we have nothing to do. The steam raised in the refrigerating machine boiler is not used directly for working the motor, but is passed into a vertical vessel, or secondary generator, consisting of an exterior steel shell containing 172 tubes, each 12 feet long and 1¾ inches outside diameter, which are fixed between tube plates. Water is admitted outside the tubes, and the boiler steam within the tubes, the steam entering at the top. In this way secondary steam is raised from the water, and the boiler steam is condensed into water, which collects at the bottom of the vessel, and is afterwards used for feeding purposes. The object of this arrangement is to obviate the variations in water level that occur in coal fired boilers, and which render it extremely difficult to accurately ascertain the height. In short trials, such as those under consideration, the exact determination of the water level at the commencement and end of the trial is a matter of very great importance, and the arrangement described was found to eliminate the variations almost entirely. A special instrument was added to the water gauge for reading the levels. This consisted of a flattened wire passing round the glass, and attached to a vernier, movable along a scale by means of a wheel and rack. At the beginning and end of the trials the exact height of the water was read, and experience showed that an accuracy within $\frac{1}{32}$ part of an inch could be easily obtained.

In the room C is a high-pressure steam-engine, which drives the shafting for the well pump, the circulating pumps, the propeller for the brine heating tank, as well as the feed water pumps; and it obtains its steam direct from the special coal fired boiler.

As already mentioned, the condensed water which collects in the lower part of the secondary boiler is used for generating the steam for working the motor. This water first passes through a cooling vessel in which it is cooled by water to a temperature suitable for feeding, and it is then delivered into a raised tank. From this tank the water passes into the measuring tank standing on a weighing machine, from which the feed pump draws its supply. No water can pass into the secondary boiler without having first entered the measuring tank, and this tank is of such capacity as to contain more than the whole of the water required during the trial. The measurement is made by ascertaining the weight on the scale at the beginning and at the end of a trial, care being taken to keep the same water level in the boiler.

The duration of each trial is $2\frac{1}{2}$ hours, and in order to give to an exhibitor the opportunity of working his machine independently of a trial just going on with another machine, separate steam conduits are arranged in the subway from the second boiler, separate arrangements being also provided for the measurement of the condensed water.

We come now to the arrangement for measuring the brine and cooling water, as well as the water discharged from the air pump. The brine cooled in the refrigerator is delivered into a measuring vessel with two compartments, each containing 264 gallons, and the inlet pipe may be turned over to the one or the other half as desired. Each compartment is provided with a valve to discharge the contents into another larger tank placed below. These valves are kept on their seat by spindles, and their tightness can be easily ascertained by inspection. In this way an accurate direct measurement of the brine circulating in a given time can be readily obtained.

From the lower tank the brine is drawn by a rotary pump and delivered into a vessel which contains the reheating apparatus, and from this vessel it returns to the refrigerator. The quantity of brine circulating per hour is, of course, regulated and made dependent on the efficiency of the refrigerating machine, and varies in direct proportion to this efficiency, since the difference between the inlet and outlet temperature is, according to the programme, always constant.

The arrangement for altering the quantity of brine consists of a by-pass on the pump discharge, through which a part of the brine can return to the tank. The pump delivers the brine through a series of coils placed in the heating tank, and from there back to the refrigerating machines. It was at first intended to surround the coils by warm water drawn from the air pump discharge, but this arrangement proved quite insufficient to obtain the desired result; the temperature of the water was not quite constant, and an unknown factor was therefore introduced.

Besides, it happened that at very low brine temperatures ice formed on those places where the circulation was not very rapid, and diminished the heating surface. It was, therefore, decided to fill up the heating vessel with brine, and to heat this by steam direct from the boiler. In this way it was found to be quite possible to bring the heating of the brine into equilibrium with the abstraction of heat in the refrigerator, excepting as regards unavoidable fluctuations. One difficulty met with was that the brine, while passing from the measuring vessel, did not fall into the tank below in a continuous current, but only at intervals. As often as the contents of 264 gallons was discharged a fluctuation arose, and it can be easily understood that considerable care was required under such changing circumstances. This difficulty was, however, overcome by careful observation.

The arrangements for measuring the cooling water for the ammonia condenser were precisely the same as those for the brine. From the ammonia condenser the cooling water passed into a pit from which the water for condensing the steam from the engine is drawn. To be certain that the engines are not left without injection water an electrical low water alarm is provided to warn the engine driver.

The water from the condenser, which was one of the jet type, is discharged into a measuring vessel with Poncelet overflow; the height over the weir being obtained by means of an iron pointer coming up from under the water. This pointer is fixed on a strong wire with bent end which is attached to a vernier. In using this instrument the position of the index is read as soon as the point appears on the surface, and the mean height over the weir is thus determined with great accuracy.

The measurement of the condensed water is accomplished by measuring the discharge from the steam traps, the pipes leading to and from the traps being coiled in a pit which is always kept full of cold water, and thereby losses through evaporation are eliminated. The steam traps answered quite satisfactorily, but to check the result the water could also be measured in a cylindrical vessel well protected against radiation and placed in the foundation pit. This vessel is accurately gauged, and the contents are read on a scale in connection with the water gauge.

The whole of the cooling and feed water is supplied from the well. The pump driven from the shafting delivers the water to an overhead tank, and from this it passes to the different pipe lines. An overflow maintains the water level uniform, so that the pressure is kept constant.

The Linde Refrigerating Machine.

It is not intended to describe in detail the construction of the refrigerating machine on the Linde system, which was submitted to the Commission to be tested. It was manufactured by the Augsburg Engine-works Company, and is of the size known as No. V., that is, it possesses a refrigerating power, equivalent to the production, in continuous work, and at ordinary speed, of 12 tons of ice per 24 hours. Such a machine is shown in Fig. 2. It consists of a jet condensing steam engine, a double acting ammonia compressor, an ammonia condenser, and a refrigerator, together with the conduits between the compressor, condenser, and refrigerator. As shown on the diagram, the compressor is laid parallel to and at one side of the steam engine, and its piston is driven by means of a connecting rod actuated by a crank, fixed to the end of the crankshaft opposite to that on which the steam engine crank is fixed.

The condenser and refrigerator consist of a series of wrought-iron coils contained in iron tanks.

The machine is charged with anhydrous ammonia, and when in operation the compressor continually draws off ammonia vapour from the refrigerator coils, and delivers it in a compressed state into the coils of the condenser, where it is condensed into the liquid form by the combined action of pressure and the cooling influence of water, which is circulated through the tank outside the coils. The pressure at which condensation occurs, depends upon the temperature and quantity of the cooling water. In the refrigerator the reverse action takes place. Liquid ammonia is admitted into the coils from the condenser and immediately vaporises, the vapour being drawn off by the compressor. The heat required for producing the change in the physical state of the ammonia is obtained in the present instance from uncongealable brine circulating on the outside of the refrigerator coils, and the pressure at which vaporisation occurs depends upon the temperature of the medium outside the coils, and the rate at which the heat is transmitted through the material of the coils. When the machine is once charged the same ammonia is used over and over again, the only loss being from leakage which in ordinary working is very trifling.

Absolute vapour tensions of anhydrous ammonia are given in Table I., from which it will be seen how the working pressures both in the condenser and the refrigerator are influenced by the variation in temperature. Thus with a temperature of 50° Fahr. condensation will occur at an absolute pressure of a little over 92 lbs. per square inch, whereas at 86° Fahr. the pressure would be over 175 lbs.; consequently, if other things are equal, the work expended in compression is increased by increase in temperature.

In the refrigerator a reduction in the working temperature means a reduction also in the boiling point of the ammonia, and consequently in the density of the vapour given off. Therefore the duty of the compressor per stroke becomes less as the refrigerator temperature is lowered, because the weight of ammonia vapour drawn into the compressor per stroke is less.

Another important factor in the efficiency of such a plant is the heat of vaporisation of the liquid. For anhydrous ammonia at atmospheric pressure this latent heat is about 550°, but as in the case of water, the actual figure varies with the pressure at which vaporisation occurs, being less with a high pressure than a low. The heat abstraction in the refrigerator therefore is reduced as the temperature is lowered, owing to the diminution in the density of the vapour, but is increased by the rise in the latent heat of vapourisation.

For these principal reasons it is obvious that the results obtained under one set of conditions, should not be taken as a criterion of the value and efficiency of a refrigerating machine.

It is quite conceivable that a machine may give good results when working under the temperate conditions of this climate, and yet be quite unfit for use under more extreme conditions. For instance, the critical point of some liquids is so low that condensation with the high temperature of cooling water that prevails in the tropics becomes a matter of difficulty if not of impossibility, and the efficiency in the tropics would therefore be very different to what it would be in temperate climates.

The Commission therefore determined to make the trials under the four different conditions set forth in the third line in Table III. The last conditions are the same as those of trial No. 2, except that the quantity of cooling water was reduced to the extent necessary to bring the condensation of the ammonia under tropical conditions; that is to say, the condensing water was running off at 90° Fahr. In this connection it may be mentioned that at Massowah, on the Red Sea, an ice making machine on the Linde system is working with the initial temperature of the cooling water as high as 102° Fahr.

In Table II. are given the dimensions of some of the principal parts of the Linde refrigerating machine, and the final results as determined by the Commission are given in Table III.

In conclusion, it may be stated, that so far as the author is aware, this is the first instance in this country in which the complete details of an independent test on a refrigerating machine have been published. It is not indeed within his knowledge that such accurate and complete tests have ever before been made, and he trusts that the paper will prove of interest to the members of the Society.

From a refrigerating point of view the most important results are given in sections B, C, D, E, and F of Table III. The results numbered 27 and 28, when compared with No. 40, are especially interesting as showing the low ratio which exists between the work done in the compressor and the actual abstraction of heat in the refrigerator.

DISCUSSION.

The PRESIDENT, in proposing that a hearty vote of thanks be accorded to Mr. Lightfoot for his very interesting paper, said that though Mr. Lightfoot's subject that evening was a cold one, he hoped that they would give it a very warm reception in the discussion. The paper which had been read was the second of the kind which had been brought before the Society by Mr.

Lightfoot, and the Society were therefore all the more indebted to the author for completing the subject. As the author had told them, the information which had just been laid before them was the result of great labour on the part of scientific men, and of great expense. To have so much information condensed into a paper and laid before the Society was a thing for which they should be very grateful. The paper would be put on record, and could always be referred to, and would be of great value to engineers.

The vote of thanks was carried in the usual way.

Mr. Schönheyder said that it would be a great advantage to the members of the Society if they could have the paper printed and put into their hands before the discussion took place upon it. The paper was a very valuable one, and he was only sorry that it was not longer. It was valuable on account of the experiments which it recorded, and which had, no doubt, been conducted with very great care. These were, in fact, the first experiments of the kind which he had known of with regard to refrigerating machines. Everything seemed to have been done to make the trials as accurate as possible. Mr. Lightfoot had said that the object of having four compartments was that several refrigerators might be tried at the same time. It did not, however, seem possible to try more than one at the same time, as there was only one boiler and one engine to supply all the steam and all the power. Something had been said with regard to the difficulties in measuring the discharge of the brine by means of the measuring tanks. Of course, if they choose to measure the brine by tanks, instead of by meter, there would be that difficulty. The difficulty arose from the fluctuation of temperatures due to the intermittent discharge from the two measuring tanks. It seemed to him that this might be got over by using one large tank underneath the two measuring tanks, the discharge from the large tank being continuous, while that from the measuring tank was intermittent. There would then be a continuous discharge into the heating apparatus, and no difficulty would arise from the sudden rise and fall of temperatures. He wished that the author had told them the duty of the different machines that were tried, but perhaps he intended to give that information in a subsequent paper. He thought that the figures given in line 54 of the same table were most valuable. They might be called the figures of merit, or efficiencies, because they compared the heat abstracted in heat units with the indicated power of the engine. One indicated horse-power was equal to 2,565,000 units per hour; and, comparing that with the work done, they found that the refrigerating work was from three times to eight times less. Strictly speaking, that was not the exact way of comparing it; but they must either compare it in that way or compare the duty with that done by other machines, which latter was really the better way, because the worked performed consisted simply in removing heat from one place to another.

Mr. ATKINSON said that the subject was a very interesting one, and Mr. Lightfoot had almost made it his own as regards England. The arrangements which he had explained appeared to be very complete and to work very satisfactorily. It was very desirable to get accurate particulars. Trial number 5, in lines 41 and 42 of Table III., were supposed to be carried out under conditions which would prevail at the tropics, but he observed that the temperature of the inlet water was still the same as it was in the other trial, viz. 49·2, and only the temperature of the outlet water was raised higher than the other. In the tropics the inlet water was possibly 100° to begin with, and the conditions were very different from those which prevailed in trial No. 5. With regard to ammonia in the tropics, the matter was very difficult indeed. A friend of his, who had a good deal of money invested in work of this kind in the East Indies, found that he lost all of his ammonia out of the machine. He had another consignment of ammonia sent out, and, when it arrived, it was found to be almost pure water, and the whole works were stopped for four or five months while ammonia was being got from England. This was a very important difficulty in connection with a running business, as it was likely to cause a loss of connection. The trials showed a really good result, and as they might be taken as absolutely without question, he thought that it was very satisfactory indeed to have a record of them. It would be very desirable to know what the other machines did during the same trial.

Mr. GEORGE A. GOODWIN said that he thought that the trials had been carried out in a most exhaustive manner, and by means which it had very seldom fallen to the lot of an engineer to be able to adopt for machines of this class. He thought, however, that the full value of the paper would not be felt until they got the results of the trials of other and similar machines. When that was done they would have some comparative data to go upon. He hoped that such results would be either communicated in an additional paper or sent to the Council in the form of a table for insertion in the transactions. With reference to Mr. Schönheyder's remark that four machines could not be tested at once, he (Mr. Goodwin), understood that each machine had its own secondary boiler, and that the evaporation in the secondary boiler was not affected by the output of steam from the main boiler, so that more than one machine could be tested at the same time, each one independently of the other. The machine which had been described was very different from those working by air compression, where the heat transformed into work in the steam cylinder at one end of the machine had some fixed proportion to the amount of cold or abstraction of heat taking place at the other; but the heat units used in the former cylinder were always a little more than those abstracted in the latter. In the chemical machines the action was quite different. For instance, in experiment No. 2, Table III., where the indicated horse-power was 18½, the result worked out at 46,800 heat units per hour, while the actual cooling in the refrigerator (line 47) was 232,440 heat units in the same time. It would be of interest to the members, but he would leave it to Mr. Lightfoot to kindly explain this, as, on the face of it, it seemed peculiar unless the scientific reasoning were understood. He should like to have a description of the arrangements of the thermometers, and also a description of the special instrument for measuring the water in the secondary generator. It was very often attention to such small details as these, which made or marred a successful test. It was not quite clear whether the condensed live steam from the main boiler passed into the measuring tank on the weighing scale and thence back to the boiler, for the author said that the tank in the scale was larger than would contain the whole of the water used during the trial, and yet he spoke of the water being returned to the boiler. If it was larger than the water used in the trial how did he measure it? It seemed that it would have been better to have had two small tanks containing only a fraction of the water required, and to fill each one alternately. He should like the author to give them the specific heat of the brine. It seemed to him that it would be about 1·21. With reference to lines 53 and 54 experiment No. 2, it appeared that the actual number of heat units in the refrigerator per hour for indicated horse-power in the steam engine was 12,729. It looked, on the face of it, as if they were only using ten pounds of water per indicated horse-power, which he thought must be an error. He should like to ask Mr. Lightfoot whether much difficulty was experienced with the ice formed around the pipes. There was an idea that although ice was a non-conductor of heat, yet inasmuch as it afforded a larger surface for the abstraction of heat from the surrounding bodies to be cooled, the one condition would neutralise the other.

Mr. SCHÖNHEYDER said that he understood that there was only one secondary boiler, and not several. Perhaps Mr. Lightfoot would answer that point to prevent misunderstanding, before the discussion proceeded.

Mr. LIGHTFOOT : There is only one.

Mr. COTT said that he thought that it would have been much more satisfactory if the power required for circulating the brine and the condensing water had been included in the table, because, after all, the total result of the ice-making power of the machine was the point which manufacturers looked at.

Mr. JOSEPH PRICE said that, having arrived at the meeting so late, he had only heard a small portion of the paper; and not having had the leisure to go into the figures shown on the printed tables in the hands of those present, he had been compelled to glean his idea of the paper to a great extent from the remarks of previous speakers, and must therefore confine his remarks to what had been said in the discussion. He quite agreed with the speaker who said that the inlet and outlet temperatures for the *quasi*-tropical trials scarcely put the test on a fair comparative basis, as inlet condensing-water at 49·6 was not at all a tropical condition.

He would have liked to have heard the question of radiation from snow-covered pipes further discussed, as he could not see that the extra surface given by the ice coating on the pipes could afford an advantage over clean pipes, but rather the contrary, as ice or snow, being in themselves slow transmitters of heat, the pipes so coated were practically to some degree insulated in consequence.

He believed that in some of the installations with which Mr. Lightfoot had to deal there had, in working, been an absence of this snow coating. Notably he might refer to a plant, which the Linde people have erected at Birkenhead, which worked very efficiently, and where, instead of snow deposit, they had a quantity of water carried away in the brine. As to the cost of circulating the brine, and of the power for the accessory engines attached to, or connected with, ice-making plant, this was, he thought, scarcely germane to the subject of the author's paper, being common to most descriptions of ice-making plant. The summary of the paper was continued in the tables, and these appear to have been made with extraordinary care; and by giving the tabular results in heat-units would, he felt sure, be very welcome to all who had to deal with refrigerating matters, as he knew of no other similarly exhaustive tables.

Mr. Stanley said that he was connected with the Pontifex refrigerating machine, which, he believed, was very well known. Two or three points in the paper had attracted his attention, and he might say that, with regard to the effect of ice forming on the brine-pipes, he had the greatest possible objection to it, and he thought that Mr. Lightfoot would confirm his view. The thicker the ice the less cooling effect there was. When a machine was at work eliminating a certain number of heat units per hour, and ice was allowed to accumulate on the brine-pipes, it was found that the brine fell lower and lower in temperature. Suppose that the ice was then scraped off the brine-pipes so as to expose the original surface of the iron to the air, the temperature of the brine would immediately rise, and more work was done on the air. Putting it practically, if they had a room which was intended to be kept at a low temperature, and it was found that they were unable to keep it at the low temperature because of the ice forming on the pipes, all that they had to do was to scrape the ice off the pipes, and then the temperature would come down. This showed, in the most practical way, that the ice was a very bad conductor of heat—so bad a conductor that the extra surface afforded by the thickness of the ice in no way compensated for its lack of conducting power. He should like to know how long the trials were conducted, as the table did not give a number of different results attained in a certain number of hours, but simply gave the average of, as he supposed, a certain number of tests in each case. He had found, after conducting some considerable number of tests, that the results were not useful unless the trial was spread over a good many hours; indeed, anything short of a ten or twelve hours' test was not of very much use. The first thing which struck him, as a maker of refrigerating machines, upon looking at the table, was the enormous reduction of heat-eliminating power in the machine when it got down to zero Fahrenheit. The machine tested, which was called a twelve-ton machine, he believed was rated in the Linde Company's books as eliminating 360,000 heat-units per hour at high temperature. On the first test, with the brine coming away at 37·4° (which, of course, was 5° above freezing point, and would, therefore, be equal to what he should call ordinary water-cooling), the machine tested eliminated 312,680 heat units per hour; that, of course, was 15 or 20 per cent. below the ordinary rated power. He did not think that there was anything remarkable in that; but when they went on they found that when the same machine, in No. 4 test, got down to 5·8 Fahr., the machine which was doing 312,680 heat units per hour only did 107,480. Supposing he wanted to eliminate a certain number of units per hour above 32° F., a certain size of machine would be required; but if he wanted to eliminate the same quantity at just below zero Fahr., he must have a machine of three times the power, and, as he supposed, nearly three times the first cost and three times the cost for working. This was a most important thing, and one which he thought all engineers who were putting up refrigerating machines should consider. He did not know what falling off there was in all other types of machines; but, unless it was as great as in this particular machine, there was, of course, a disadvantage in this machine when it was working at low temperatures. In the Pontifex absorption machine, working under these conditions, the reduction of efficiency was only about half as great. The next thing he noticed was the great reduction of the work done when the condensing water was short. He did not mean by that, when they had not enough condensing water to extract the number of heat units that the machine was doing, but simply when the condensing-water was coming away at 95·6° Fahr, as shown in test No. 5. As had been pointed out, this machine, in working with an initial temperature of condensing-water of 49·6° Fahr., and with the water coming away at 95·6° Fahr., was not at all working under tropical conditions. Tropical conditions meant, perhaps, 95° Fahr. going in, and 100° or even 105° coming out. After a little experience of tropical machines, he found that, in order to get a fair amount of work out of the machine, it was requisite to have an enormous flow of condensing water in the machine. Practically, there must be a river running through it in order to get anything like useful work; and in saying this he was speaking from his own experience. Nothing, however, in the way of unlimited supply at a comparatively high temperature would be equivalent to getting the initial water at 49·6°. This water was used in a condenser only; the initial temperature was 49·6° Fahr., and the exit temperature was 95·6° Fahr., the mean temperature being 72·6° Fahr. He thought that it might be fairly argued that the machine under those conditions was only in the position of working with condensing water at 72·6° Fahr. Another point which he noticed was that, even with the water going in at 49·6 Fahr., and coming out at 95·6° Fahr., the machine did such a very much smaller quantity of work than when it was up at the high temperatures, although the falling off there was nothing like so great as when they got down to zero. He should like to ask Mr. Lightfoot, with regard to the case at Massowah, where he had condensing-water at the initial temperature of 102°, what was the amount of work which the particular machine exerted in proportion to the nominal power of the machine? Again, it was well, when they were taking out the indicated horse-powers per hour, to give some indication, at any rate, of the extra power required to circulate the brine and the condensing-water, or, at all events, the brine. The condensing-water was often supplied from other sources, but the machine nearly always had to pump its own brine. As a number of questions had been asked as to the comparative power and efficiency of this particular machine, as compared with other machines, he was sorry to say that he had not come prepared with any exact figures. He had, however, in his mind a test he had very recently conducted with a Pontifex absorption machine. The machine which he referred to was one of half the nominal power of the one in the table. With the brine coming out at 18°, it eliminated about 180,000 heat units per hour. The condensing water went in at 48°, and was supplied under similar conditions to the No. 5 trial shown in the Table. As the quantity used was only about 640 gallons per hour, it was coming away at something like the temperature of No. 5 trial. The steam used per hour in that machine was about 550 lbs., so that with this machine, making a correction for the fact that in the case he had mentioned the brine was coming away at 23 instead of 18 (which, at the Linde Company's usual allowance, would bring the 197,400 heat units per hour of the Linde to about 180,000, the quantity which he mentioned), it would be seen that what was called a 6-ton Pontifex machine did practically the same work under the same conditions as a 12-ton Linde machine while using 100 gallons of condensing water per hour more. This was as nearly as he could state the matter, not having the exact figures before him. In this case the steam used also included that which was required for the brine circulation. They ought to be very much obliged to Mr. Lightfoot for his valuable paper. As had been stated, no exact reliable tests, conducted by independent people, had been previously put before the public with regard to these machines. This paper showed the various conditions which had to be met.

Mr. Goodwin said that he was glad to hear the last speaker's remarks about the ice on the pipes, because they exactly agreed with his own opinion which he had held for some time. The other day he was speaking with a manufacturer of these chemical machines, and he asked him a question on that particular point, the answer he received was that the larger diameter due to frost neutralised the deterrent effect of the coating being a bad conductor, and it was simply to get the opinion of the author and the members present that he brought the matter forward.

Mr. Lightfoot in reply to the discussion said, with regard to Mr. Stanley's remarks, that the number of revolutions at which the Linde machine worked at the trials was only about 45 per minute, that being the speed fixed by the Committee, for the reason stated in the paper. The ordinary number of revolutions at which the machine actually did work, under normal conditions, when put to some industrial purpose, was 60 to 70, and the units dealt with by that machine would therefore be increased in proportion of 45 to 60 or 70, and would far more than come up to the figures given in the Linde Company's circulars. There was in fact no reason why the machine should not do nearly double the refrigerating work given in the Tables, if required, as the compressors could very well work up to 80 or 90 revolutions per minute, and indeed constantly did so.

He was much surprised at the remarks of many of the speakers, including Mr. Stanley, to the effect that tropical conditions of condensation cannot be obtained so long as the temperature of the cooling water entering the condenser is low. This is of course wrong. By reducing the quantity of the water, tropical conditions can not only be reached but far exceeded, and in the case of experiment No. 5, it will be seen by reference to the figures in line No. 31 in the Table III., that the condensing temperature of the ammonia vapours was in fact 95·4° Fahr. This may not be as high as is sometimes actually attained in the tropics, but the case was not given as representing extreme tropical conditions, but merely to show the effect of diminishing the flow of cooling water to the extent specified. At Massowah, as has been stated, the initial temperature of the water is 102° Fahr., but there the compressor is worked on Professor Linde's compound system, by means of which the losses due to high temperature of cooling water are practically eliminated. This compound system of working is always adopted by the Linde Company for machines running under tropical, or even semi-tropical conditions, and generally also for machines for use on board ship. It is quite impossible to give any proportion between work actually done and nominal capacity as asked for by Mr. Stanley. It is the author's practice, except in extremely special cases, to design each plant for the work it has to perform, and the nominal capacity is therefore the actual capacity. The duration of each trial was, as stated in the paper, 2½ hours, and each experiment was afterwards repeated by an entirely independent set of observers. When a refrigerating plant such as has been described, is in normal work, and provided with complete measuring appliances, the actual refrigerating duty can in fact be ascertained with great accuracy in a very few minutes, and he therefore does not agree with Mr. Stanley that prolonged trials are necessary. It may be so with some machines which are difficult to regulate, and in which the refrigerating duty is constantly varying, but it is not the case with the Linde machine.

With regard to the falling off in the duty at low temperatures, that was a matter which did not depend upon the construction of any particular machine, but, as had been stated in the paper, it depended upon the physical properties of the refrigerating agent. It could not be avoided, and the duty at any temperature could easily be calculated by those conversant with the subject.

The results of the working of the 6-ton absorption machine were interesting so far as they went, but they were incomplete, and therefore useless for comparison. Besides, they were not made by independent persons. He should be glad if Messrs. Pontifex and Wood could see their way to send a plant to Munich to be tested independently under the precise conditions obtaining in the trials of the Linde machine. In his opinion it was impossible, for well known physical reasons, that an absorption machine could produce a given refrigerating effect with anything like the same economy and regularity that could be attained with a compression machine working with anhydrous ammonia. This appears to be practically proved from the fact that comparatively very few absorption machines are in use, though they have been before the public for very many years.

Mr. Goodwin had referred to the effect of ice upon brine pipes. There could be no doubt that the effect was deleterious, and that the thicker the coating the less efficiently was the refrigerating work performed. A test made with a machine when refrigerating a given capacity of stores with clean brine pipes would give results very different from those obtained in actual working, when the pipes would be covered with ice. These remarks apply equally to what are known as direct expansion pipes, as to pipes in which cold brine is circulated. To overcome, or rather to avoid this loss, and the many other objections appertaining to the use of pipes in the rooms, the air cooling apparatus referred to by Mr. Price has been introduced. By means of this apparatus a current of dry cold air is produced, external to the cooling rooms, without the formation of ice, and in this way the refrigerating duty is always maintained at a maximum. The air is circulated to and from the rooms by means of a fan.

Mr. Schönheyder seemed to think it was of no use to provide space for four refrigerating machines, when there was only testing machinery for one. The extra space was provided that one or two machines might be erected and got ready while another was being tested. It was true that only one actual official trial was made at one time, but by means of steam taken direct from the coal-fired boiler, preliminary trials could be made. At present only two machines had been tested, namely, Lindes, and a machine on the Pictet system. The results with the Pictet machine were not as good as those obtained with the Linde machine. A carbonic acid machine was now being prepared for trial, but it was not anticipated that the results would be satisfactory, especially with high temperatures of cooling water, for, as was well known, the critical point of carbonic acid was reached at about 87° Fahr., and at that point condensation became impracticable, and the machine would then work practically as a cold air machine, and with the same want of economy. Even long before the temperature of 87° was reached, the power to be expended in driving the machine would become very great. Many years ago machines using carbonic acid as a refrigerating agent were supplied by the Linde Company, but they were abandoned in favour of anhydrous ammonia on account of the much greater economy in working. The experiments with the carbonic acid machine are to be made not so much on account of their commercial value, but with the view of ascertaining exactly the behaviour of carbonic acid under various conditions of working. The results will be published by the Committee.

The brine feed from the tank was continuous. The two measuring tanks discharged into one larger tank below, from which the rotary pump drew its supply. The fluctuations referred to in the paper were due to the influence of the outside temperature. They were not very great, but they had to be guarded against in an exact experiment of the kind described.

He was acquainted with the trouble that Mr. Atkinson's friend had with his ammonia machine, but he believed that it was not a compression machine, but one of the absorption type, such as Mr. Stanley had referred to. Of course the ammonia used was not anhydrous, but the ordinary *aqua ammonia* of commerce. When that preparation was sent out to a hot climate the ammonia very quickly evaporated.

Mr. ATKINSON said that the machine was not a compression machine pure and simple, but still there was a difficulty about the high temperature.

Mr. LIGHTFOOT said that he believed he knew the machine to which Mr. Atkinson referred.

Mr. STANLEY: I cannot say that I do, Mr. President.

Mr. LIGHTFOOT said that he had not mentioned whose machine it was. He had only said that it was an absorption machine. As to the secondary boiler, he had already stated that there was only one. He believed that the relation of the work in the steam cylinder to the actual work or duty in the refrigerator had been already dealt with by Mr. Schönheyder. There was *primâ facie* no reason why any work should be expended at all, seeing that the work of refrigeration was merely the handing of a quantity of heat from one body to another. The feed arrangements were as follows:—The water that was condensed in the secondary generator was at a high temperature, and could not be passed direct as feed water into the other portion of the secondary generator. It had therefore first to be cooled, and it was then passed through the measuring tank, and by means of the pump was delivered into the secondary generator where steam was raised for working the machine. It was the cooling water which was used for feeding the primary boilers. He could not agree with Mr. Cott that the power for working the brine and water pumps should be included in such a test as this. It seemed to him obvious that it should not, because in a test such as this the pumping arrangements were very special, and consequently it would give no possible guide as to the total power required in an ordinary installation either for refrigerating or for ice making. There was no doubt that in an experimental station such as this, the power consumed for the subsidiary operations was very large indeed compared with the actual refrigerating work, much larger than in actual practise.

Mr. Goodwin had asked a number of questions which he thought could be readily answered by reference to the Tables. The specific heat of brine was given in the Table. In experiment 2 the quantity of feed water is given in line 15. This is also obtained by dividing the figures in line 54 by those in line 53, the result being 22·44 lbs. The reason that the heat abstracted in the refrigerator is so much in excess of that developed in the steam cylinder is due to the fact that in the Linde system heat is abstracted in the refrigerator, and to a large extent rejected in the condenser, during a change in the physical state of the refrigerating agent. Consequently there is no direct relation between the energy developed in the steam cylinder and the heat abstracted in the refrigerator, as there is in the case of a compressed air machine. The relation varies according to the physical properties of the agent, but of all agents of which the author has knowledge, none possess such a combination of properties so specially suitable for refrigerating purposes, as anhydrous ammonia.

28	Thermal equivalent of this horse-power, per hour	heat units	39560·0	38720·0	36440·0	32160·0	55680·0
29	Mean absolute pressure in lbs. per square inch — Condenser		135·47	131·21	127·8	126·24	199·23
30	Mean absolute pressure in lbs. per square inch — Refrigerator		55·24	41·89	30·25	22·15	41·89
31	Equivalent temperatures of saturated Ammonia vapours — Condenser	degrees Fahr.	72·5	70·7	69·2	68·5	95·4
32	Equivalent temperatures of saturated Ammonia vapours — Refrigerator	degrees Fahr.	26·8	14·5	0·3	−11·7	14·5

[C] REFRIGERATOR.

33	Mean temperature of brine — Inlet	degrees Fahr.	42·8	28·4	14·0	−0·4	28·4
34	Mean temperature of brine — Outlet	degrees Fahr.	37·2	23·0	8·6	−5·4	23·0
35	Difference in temperature	degrees Fahr.	5·6	5·4	5·4	5·0	5·9
36	Quantity of brine per hour	Gallons.	6505·2	5036·5	3557·0	2426·6	4210·6
37	Specific gravity of brine at 63·5° F.		1·250	1·250	1·251	1·250	1·247
38	Specific heat per gallon at above temperature		0·859	0·854	0·828	0·890	0·831
39	Ascertained Refrigerator duty per hour	heat units.	312680·0	232100·0	159200·0	107480·0	197400·0
40	Actual refrigerator duty per hour corrected for differences in temperature at commencement and at end of trial	heat units per hour.	312560·0	232440·0	159120·0	107440·0	197440·0

[D] CONDENSER.

41	Mean temperature of cooling water at Inlet	degrees Fahr.	49·2	49·2	49·4	49·4	49·6
42	Mean temperature of cooling water at Outlet	degrees Fahr.	67·4	67·2	67·6	67·4	95·6
43	Difference in temperature	degrees Fahr.	18·2	18·0	18·2	18·0	46·0
44	Quantity of cooling water per hour	gallons	1933·8	1504·1	1070·7	775·7	537·2
45	Ascertained Condenser duty per hour	heat units	358640	275960	199160	142600	250560
46	Actual Condenser duty corrected for difference in temperatures at commencement and at end of trial		358680	276000	199380	142640	250640

[E] BALANCE OF HEAT.

47	Actual Refrigerator duty	heat-units per hour	312560	232440	159120	107440	197440
48	Thermal equivalent of indicated Compressor horse-power	ditto	39560	38720	36440	32160	55680
49	Total of 47 and 48	ditto	352120	271160	195560	139600	253120
50	Actual Condenser duty	ditto	358690	276000	199280	142640	250640
51	Difference	ditto	−6560	−4840	−3720	—3040	+2480
52	The same in per centage of Condenser duty		−1·8	−1·8	−1·9	−2·1	+0·1

[F] FINAL RESULT.

53	Actual number of heat units in Refrigerator per hour	for one pound of feedwater excluding pipe condensation	773·8	567·4	411·9	296·8	368·5
54	Actual number of heat units in Refrigerator per hour	for one indicated horse-power in steam engine	17230	12729	9343	6844	8088

TABLE I.

Degrees Fahr.	Absolute pressure in pounds per square inch.
-40	11·0
-22	17·3
-4	27·8
+23	55·0
32	61·7
50	92·2
68	128·0
86	175·6
104	234·5

The dimensions of the principal parts of the Linde Refrigerating Machine are given in Table II., and the final Results as determined by the Commission in Table No. III.

TABLE II.

MAIN DIMENSIONS OF CYLINDERS.

		Steam Eng.	Compressor.
Diameter of Cylinder	inches	12	$9\frac{7}{8}$
Diameter of Piston Rod	,,	$1\frac{7}{8}$	2·$\frac{3}{16}$
Actual Piston Area	front sq. ins.	110·3	72·84
	back ,,	113·1	76·58
Stroke	inches	$27\frac{1}{2}$	$16\frac{1}{2}$
Volume per Stroke	front cub. ins.	3033·3	1201·8
	back ,,	3100·3	1264·6
	mean ,,	3071·5	1232·4

REFRIGERATOR AND CONDENSER SURFACES.

		Refrigerator	Condenser
Diameter of Tubes ...	outside, inches	$1\frac{19}{32}$	$1\frac{1}{2}$''
	inside ,,	$1\frac{1}{4}$	$1\frac{3}{16}$
Length of Tubes below Water & below Brine, ft.		1825·32	1824·37
Total Surface	outside, sq. ft.	762·48	726·84
	inside ,,	603·74	565·92
	mean ,,	683·64	645·84
Quantity of Brine and Cooling Water in the apparatus	... cub. ft.	190·73	191·79

NOTE.—*The little difference between the actual surface and the stipulated one of* 712·8 *was disregarded by the Commission.*

TABLE III.

			1	2	3	4	5
1	Date and number of Trial		11 Jan., '90.	3 Jan., '90.	4 Jan., '90.	7 Jan., '90.	9 Jan , '90.
2	Temperature of Brine	...degrees Fahr.	42·8 to 37·4	28·4 to 23	14 to 8·6	—0·4 to —5·8	28·4 to 23
	[A] STEAM ENGINE.						
3	Total quantity of feedwater per hour	lbs.	429·66	438·02	414·48	389·84	562·54
4	Water condensed in steam pipes per hour	lbs.	25·74	28·38	28·16	27·94	26·84
5	The same in percentage of the total quantity of water	...	6·0	6·5	6·8	7·1	4·8
6	Effective feedwater per hour...	lbs.	403·92	409·64	386·32	361·90	535·70
7	Mean temperature of feedwater	...degrees Fahr.	70·8	69·6	83·8	74·0	70·8
8	Mean pressure above the atmosphere in vertical boiler ..	lbs. per sq in.	75·97	74·63	75·4	75·4	75·6
9	Mean pressure in steam cylinder in lbs. per square inch...	front	26·242	26·313	25·02	24·402	33·555
10	Ditto ditto ditto	back	24·736	24·765	22·692	20·874	35·889
11	Mean number of revolutions per minute	...	44·91	45·10	45·05	44·76	44·97
12	Mean indicated horse-power	front	9·22	9·29	8·82	8·20	11·81
13	Ditto ditto	back	8·92	8·97	8·21	7·50	12·60
14	Total indicated horse-power	...	18·14	18·26	17·03	15·70	24·41
15	Feedwater per indicated horse-power per hour	lbs.	22·26	22·44	22·68	23·03	21·96
16	Mean vacuum in inches of mercury...	...	26·5	25·8	26·1	26·1	25·9
17	Mean Barometer reading in inches of mercury	...	28·5	28·2	28·4	29·1	28·8
18	Water condensed in steam-jacket per hour	lbs.	63·58	57·2	54·56	52·14	52·8
19	Ditto in percentage of the effective feedwater	...	15·7	14·0	14·1	14·4	9·9
20	Actual steam entering steam cylinder per hour	lbs.	340·34	352·44	331·16	309·78	482·9
21	Total water discharged from the air-pump per hour	lbs.	17115·34	15135·34	14756·28	8571·64	13999·3
22	Injection Water per hour	lbs.	16775·0	14783·34	14424·5	8261·88	13316·4
23	Ratio of $\left\{ \frac{\text{Injection water}}{\text{Quantity of Steam entering cylinder}} \right\}$	...	49·3	41·9	43·5	26·7	28·0
24	Temperature of Injection water	... degrees Fahr.	67·2	66·7	58·1	44·3	55·6
25	Temperature of water discharged from air pump	...	88·0	89·4	79·8	97·3	89·4
	[B] COMPRESSOR.						
26	Ratio of $\left\{ \frac{\text{Indicated horse-power in Compressor}}{\text{Indicated horse-power Engine}} \right\}$		0·8561	0·8326	0·8403	0·8046	0·8954
27	Indicated horse-power Compressor	...	15·53	15·20	14·31	12·63	21·86
28	Thermal equivalent of this horse-power, per hour	heat units	39560·0	38720·0	36440·0	32160·0	55680·0
29	Mean absolute pressure } Condenser	...	135·47	131·21	127·8	126·24	199·23
30	in lbs. per square inch } Refrigerator	..	55·24	41·89	30·25	22·15	41·89
31	Equivalent temperatures } Condenser	... degrees Fahr.	72·5	70·7	69·2	68·5	95·4
32	of saturated Ammonia vapours } Refrigerator	... degrees Fahr.	26·8	14·5	0·3	—11·7	14·5
	[C] REFRIGERATOR.						
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34	of brine } Outlet	... degrees Fahr.	37·2	23·0	8·6	—5·4	23·0
35	Difference in temperature	... degrees Fahr.	5·6	5·4	5·4	5·0	5·9
36	Quantity of brine per hour	Gallons.	6505·2	5036·5	3557·0	2426·6	4210·6
37	Specific gravity of brine at 63·5° F	...	1·250	1·250	1·251	1·250	1·247
38	Specific heat per gallon at above temperature	...	0·859	0·854	0·828	0·890	0·831
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40	Actual refrigerator duty per hour corrected for differences in temperature at commencement and at end of trial	... heat units per hour.	312560·0	232440·0	159120·0	107440·0	197440·0
	[D] CONDENSER.						
41	Mean temperature of cooling water at { Inlet	...degrees Fahr.	49·2	49·2	49·4	49·4	49·6
42	{ Outlet	..degrees Fahr.	67·4	67·2	67·6	67·4	95·6
43	Difference in temperature	...degrees Fahr.	18·2	18·0	18·2	18·0	46·0
44	Quantity of cooling water per hour	...gallons	1933·8	1504·1	1070·7	775·7	537·2
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46	Actual Condenser duty corrected for difference in temperatures at commencement and at end of trial ... ... }	... ..	358680	276000	199380	142610	250640
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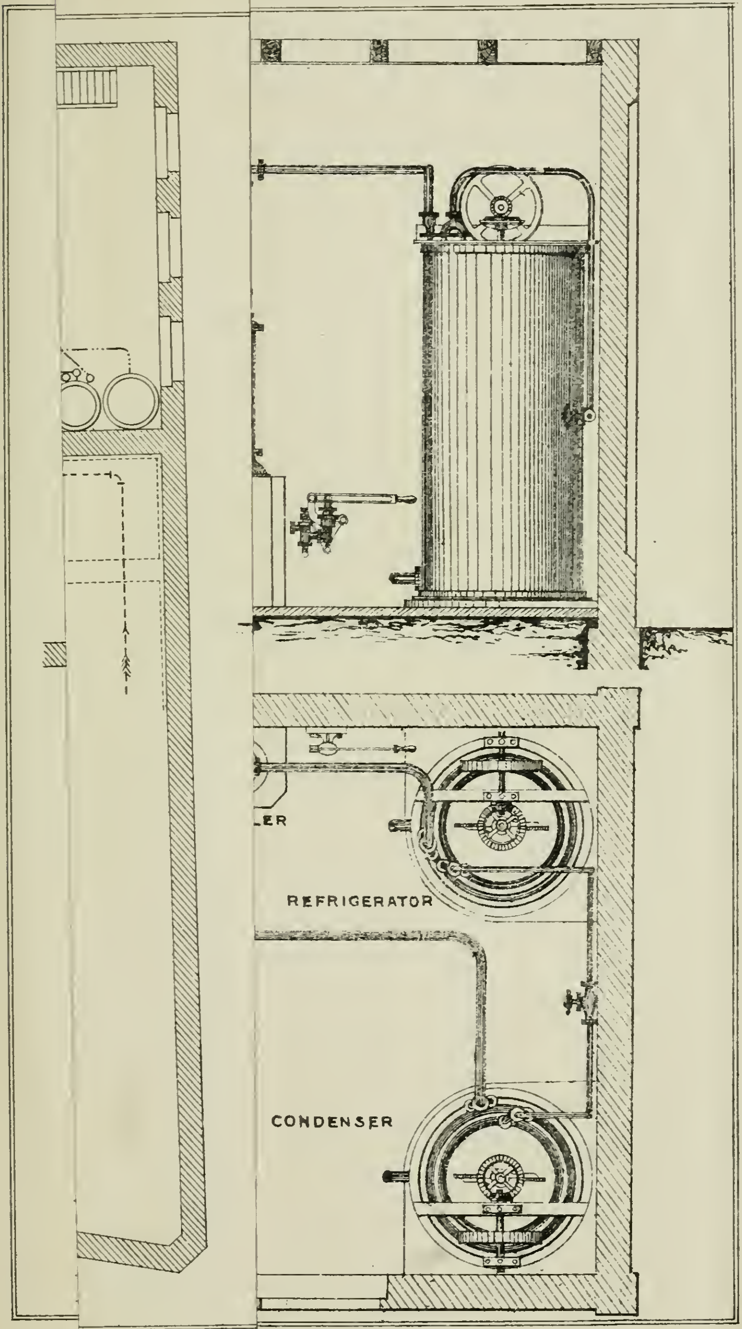
52	The same in per centage of Condenser duty	...	—1·8	—1·8	—1·9	—2·1	+0·1
	[F] FINAL RESULT.						
53	Actual number of heat units in Refrigerator per hour	for one pound of feedwater excluding pipe condensation	773·8	567·4	411·9	296·8	368·5
54		for one indicated horse-power in steam engine	17230	12729	9313	6844	8088

Plate 1.



don & New York.

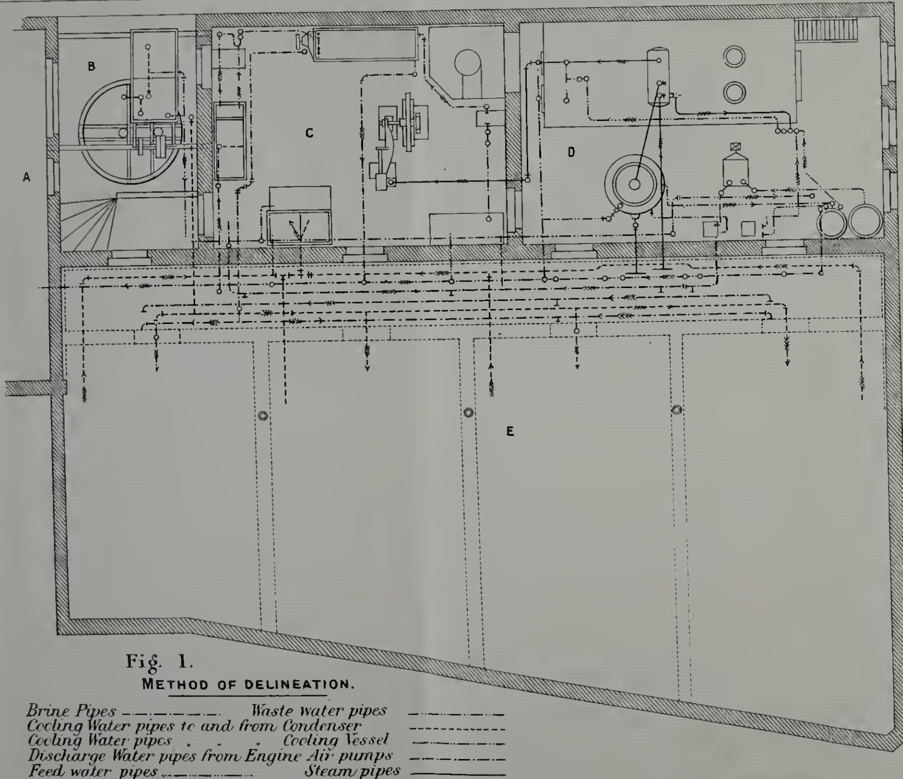


Fig. 1.

B
C
D
A
E
METHOD OF DELINEATION.
Brine Pipes
Waste water pipes
Cooling Water pipes to and from Condenser
Cooling Water pipes . . . Cooling Vessel
Discharge Water pipes from Engine Air pumps
Feed water pipes
Steam pipes

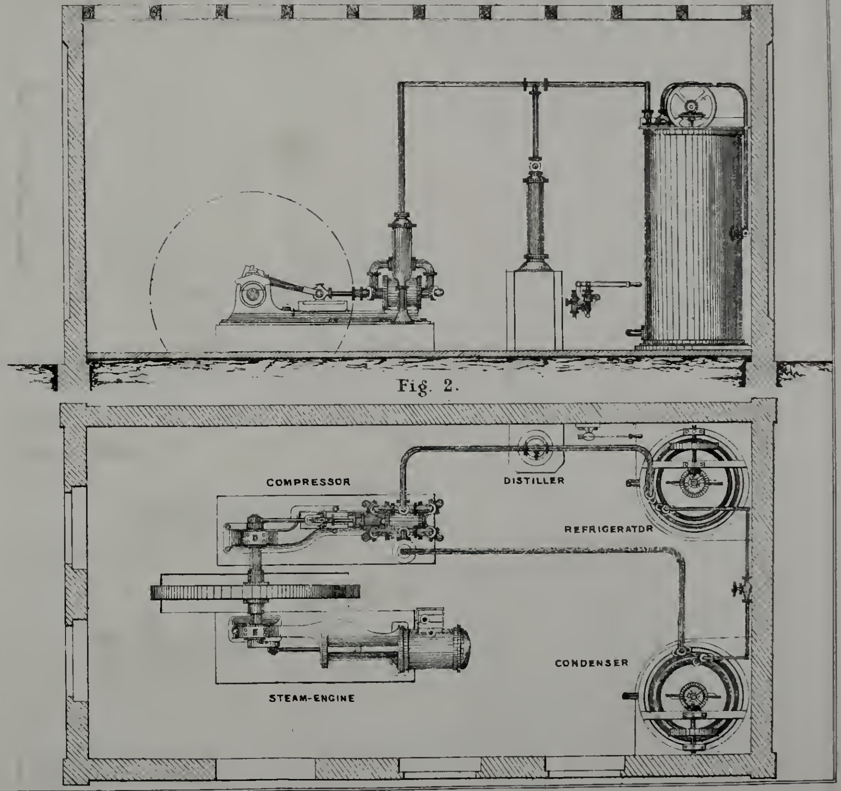


Fig. 2.

E & F N. Spon, London & New York

May 4th, 1891.

J. W. WILSON, VICE-PRESIDENT, IN THE CHAIR.

MODERN COAL GAS MANUFACTURE.

BY CHARLES CLAUDE CARPENTER.

IF any apology be needed for reading a paper on the above subject before this Society, the author ventures to hope it may be found to some extent in the fact, that beyond the circle of the interested, but scant information appears to exist among the engineering profession as a whole, of the branch thereof whose magnitude may be estimated from the fact that in its operations, upwards of ten million tons of raw material are dealt with annually in the United Kingdom alone.

And if at the same time the paper can be made to serve as a convenient basis from which to discuss some among the many vexed topics which are of particular interest to gas engineers themselves, the author will feel that his having brought this matter forward, will not have been altogether without justification.

It ought, perhaps, to be stated at the outset, that it is not proposed to deal with the subject from an historical standpoint, except so far as may be necessary to more fully explain the rationale of any particular process.

CARBONISING.

Ordinary coal gas is produced, or "made," by carbonising coal at a full orange heat in fire-clay retorts. These may be made in cross section either circular, D-shaped, or elliptical; the latter are almost universally called "oval" by gas makers, and the term will therefore be used throughout this paper in preference to the more strictly correct one.

The diagram, Fig. 1, shows these three kinds, their areas being equal, and they are represented as charged with a like weight of coal.

The disadvantages of the circular form are manifest when it is remembered that the surrounding heat has to penetrate to the centre of the contained mass of coal in order to drive off its volatile constituents, and as might be expected, it is generally found in working that the core of the otherwise burnt-off charge consists of only partially carbonised coal. Both D's and ovals are free from this important defect, and theoretically as well as in the opinion of the majority of engineers, of the two the D has the advantage. But the author's experience of ovals on a large scale as compared with that of other engineers working under precisely similar conditions with D's, has convinced him that this supposed advantage is an imaginary one, and that no increase in quality or make per ton can be placed to the credit of the latter.

Further, they are more difficult to "draw"; a stoker will take at least half as long again to draw one of this type clean, as compared with an oval, while they are obviously not as strong nor so suited to resist wear and tear, being inherently weak at the corners.

In addition, the self-sealing lids are more difficult to keep tight, and the shape of the mouthpiece does not lend itself so well to the best disposition of the curved pipes, or "ascension bends," conveying the gas from the retorts.

The author has now at work gas-fired, oval clay retorts, which have been in use for 1600 working days under modern conditions of production, a record which has probably been neither excelled nor equalled.

The retorts are heated in a "setting," this being the name given to the arch or oven within which they are built.

Settings are used containing from one to eleven retorts, but those most generally used have from six to ten as shown in Fig. 2.

Dealing with these in their order, "sixes" are convenient in narrow arches, since they permit of a large "combustion chamber" being used; but they are not the most economical either in floor space or in fuel consumption. The setting of "sevens," shown next to the foregoing, is a much better arrangement, indeed, in some respects an ideal one, for the retorts are placed almost equidistant around the heating zone, and the course the waste gases have to take allows as much as possible of their useful effect being absorbed before their exit to the flues. The second setting of "sevens" is a bad though not an uncommon one, and should be carefully avoided. The centre retort, or "bull's-eye" as it is called, is sure to be overheated if the others are kept to their proper temperature, and this too, in spite of the additional "shielding" which is essential; the extra wear and tear induced thereby affects the stability of the other retorts placed round it, and its ascension pipes give more than the average trouble by "stopping."

Almost the same remarks apply to the "eights." The author has known the lower "centre-middles" to burn out regularly after six months working, while the others in the bench worked for two seasons.

The "nines" is a very good type, provided sufficient room is left between each vertical tier of retorts to allow of proper combustion taking place.

The "tens" is a useful and economical setting, both as regards floor space and fuel consumption. Its great objection, however, lies in the fact that a secondary travelling charging floor or stage has to be provided from which to stoke them.

As to "elevens," so far as the author is aware, the only works where these are in use is the Old Kent Road Station of the South Metropolitan Gas Company. Their object was to reduce the waste in both labour and coke for heating which existed with "sixes" or "sevens."

But developments in gaseous firing have rendered possible the attainment of those desirable ends by simpler means.

Retorts may be either "singles" or "throughs."

The former are worked from one end only, and are half the length of the latter which are charged and drawn simultaneously from both mouthpieces. "Singles" deserve mention as they have been advocated by some as a preventive of stopped ascension pipes, an evil which will be dealt with later on, but the authors' experience does not tend to confirm this belief, and the latter system has many attendant disadvantages as regards working.

In either case the retorts are supported within the setting upon cross walls or bearers, the distances between which vary from eighteen to nine inches. This last is undoubtedly the best, and gives excellent results as regards stability and durability. The retorts may be made and set in lengths of from five to ten feet, or they may be built up *in situ* from tiles or bricks moulded to the proper shape, and provided with rebated joints and keys.

Those constructed on the first-named plan are called "clay retorts," as distinct from "tile retorts" or "brick retorts" as the case may be.

Clay retorts have this disadvantage, that the cracking which takes place irregularly throughout their length is only backed up where the walls come, between which pieces not unfrequently fall out into the setting, to the more or less injury of the retort. On the other hand, with "built" retorts, whether of tiles or bricks, it is at these joints that contraction and expansion take place, and this can easily be provided for by means of the rebates and keys. They are of course more costly to set, but properly fired, they will last probably four or five times as long, and repairs can be effected with great facility.

Regarding the increased consumption of fuel which is sometimes urged as a reason against their adoption, the author would say that at least in the case of tile-built retorts, the cause must be looked for rather in the construction of the setting itself than in the retorts composing it. Sections of each kind are shown in Fig. 3.

Retort Heating and Working.

It used to be said that gas companies' dividends were made in the retort houses, and certainly, whether this was true or not, on no part of the plant has more care or thought to be bestowed than in the choice of a system of retort setting and firing, for on it depends efficiency in carbonising, and economy in fuel, in labour, and in wear and tear.

Until about ten years ago almost the whole of the firing was effected by direct-acting furnaces. Each setting had its own furnace placed usually between the two bottom retorts, and and in which coke was burnt on a grate consisting of one or more bars, kept from rapid wasting by the steam from a water ash pan beneath. The operation of clinkering was performed by emptying the furnace of its contained fuel about four times in the twenty-four hours, breaking up the clinker which fell into the pan, and filling up again with what was generally cold coke. The introduction of gaseous firing, however, has revolutionised these wasteful methods, and its history as applied to retort heating alone, would form subject matter enough for an extensive paper.

It will here suffice to state in general terms its present position.

In Scotland, the Siemens outside producer, as improved by Mr. W. Foulis, is now largely used. It consists of a circular chamber formed within a sheet-iron casing and lined with fire-brick. It has an open hearth and is provided at the top with a charging door and a short cross flue, by which communication is made with the setting. The producer gas on entering this, meets two streams of highly heated air from the regenerators, and combustion thereupon takes place, its destructive effect being moderated by a judicious arrangement of brick baffles.

This system does not appear to have met with much success where coke other than that from Cannel or shale has to be used, the chief difficulty being in the maintenance of a constant supply of primary air under the ever varying conditions of the hearth. Distinct from the above is the closed grate producer, now, in one or other of its forms, almost universally used.

The fuel to be gasified rests upon fire-bars, access to which for clinkering is obtained through faced doors, preferably of the full width of the grate. Clinkering is performed in the well-known way by supporting the incandescent fuel with flat bars driven in above the clinkers which fall into the pan when the lower ones are withdrawn.

On these being replaced all is ready for the producer to run for another twenty-four hours. The furnace doors being faced, the supply of primary air is under perfect control, since none can obtain access to the fuel except through the regulating slides.

Above the producer is the retort setting, communication with which is effected by ports or nostrils formed in the furnace arch.

Through these the gas rises, meeting on its way the heated secondary air. Combustion ensues, and the products thereof after circulating round the retorts pass through the regenerator on their way to the chimney.

In 1886 the author introduced some modifications of the above, designed to reduce the initial outlay for erection, as well as to effect further economies in the cost of working. Instead of providing every setting with its own furnace, he placed four or five in communication with one gas-producing centre, arranged conveniently for feeding with fuel, the amount of gas going to each being controlled by a damper.

Regenerators were dispensed with, the secondary air being heated to the required degree by its passage through a shallow flue formed on the floor of the setting. By this means wear and tear have been largely reduced, and less labour is required for firing than is possible in any other plan. The arrangement is working well in various parts of the country, but is not recommended for small works.

The retorts when properly heated have to be charged with coal, this being at present generally done by means of shovels or scoops. To substitute machinery for the efficient performance of the work is a problem which has vexed the minds of many and is full of interest and importance, but as the author understands that a paper dealing with the whole question will shortly be read before this society, he does not propose to touch upon the matter himself. One important subject which is engaging the serious attention of gas engineers deserves however to be noticed, namely, the introduction of Sloping retorts. The first patent for these was taken out nearly twenty years ago, but it has remained for a Frenchman, Monsieur Coze, to put the idea into working shape.

The retorts instead of being placed horizontally, are set at an angle varying from 29 to 36 degrees, the angle of repose of coal being within these limits. The charge is tipped in at the top end, and spreads itself in an even layer over the bottom of the retort. When properly carbonised, the lower door is opened, and but a slight inducement is needed for the red-hot coke to run itself out. To obtain the fullest advantages of this very ingenious system, however, very considerable alterations will have to be made in the present methods of storing and supplying the coal.

Collecting the Foul Gas.

The gas as produced by the carbonising of the coal leaves the retort by means of an "ascension" pipe rising from the mouthpiece, and passes through the bridge-piece into the hydraulic main.

As regards the ascension pipe, this should be as short as possible, so as to avoid any condensation therein, the effect of which is to increase its tendency to choke. The bridge-piece is shown in its various forms in Figures 4 to 10 B, which are taken from a standard work and given here as instructive in showing every case save one (Fig. 10B), how these should *not* be made. The correctly designed one is that which allows all condensable matters to gravitate easily to the hydraulic main.

The hydraulic main serves the purpose of an automatic cut-off between the retorts and the other part of the plant.

It remains at the present day in much the same form as was introduced by Clegg, mechanical anti-dip valves being now generally discarded. About nine-tenths of the total tar is deposited in the retort house mains, from which the gas passes on to the condensers, where the temperature is reduced to the normal, and thence to the Exhausters.

Exhausters.

The function of the exhausters is to draw the gas under a partial vacuum from the retort houses and force it through the purifying apparatus to the gasholders.

Various patterns of both reciprocating and rotary are in use, but the most common type is the improved Beale. Figures 11, 12, & 13, show the original Beale pattern and its modification by two subsequent patents to its present very perfect form, in which the "slide" is guided by a central pin instead of the segments and rings of the earlier kinds.

It should be stated that in the best designed modern practice, they are driven by compound condensing engines, the steam being raised in many cases by burning breeze, the London market value of the latter being at present under two shillings a ton.

WASHING AND SCRUBBING.

The gas as it leaves the Exhauster has to be freed from the light tarry vapours which escape condensation. The most effectual apparatus for this purpose with which the author is acquainted, is the Livesey Washer. This consists of a series of horizontal tubes of peculiar construction, perforated with a large number of small holes, and partly immersed in ammoniacal liquor.

Through these the gas is forced, and the number of fine streams into which it is cut up, causes the tar to be rubbed out of it, so to speak; the presence of the foaming liquid materially assisting the operation, and preventing clogging of the holes.

Purification from Ammonia and other soluble impurities associated therewith, comes next. To effect this the gas is passed either through a tower-scrubber or a washer-scrubber.

The former is a vertical cylinder, forty or fifty feet in height, filled with some surface-giving material such as coke, drain pipes, canvas screens, thin boards on edge, etc., the two last mentioned giving excellent results.

Clean water is run in at the top of the vessel, and meeting the ascending gas dissolves its impurities and overflows at the bottom as ammoniacal liquor. The author has experienced considerable advantage from lagging the scrubbers internally to the extent of four or five inches thickness.

The washer-scrubber is a horizontal machine traversed by a shaft on which are carried drums revolving in separate chambers or divisions, half filled with water. These drums are constructed so as to expose to the gas which is forced through their upper half, a very large area of continually wetted surface, its action being the same as in the tower-scrubber.

PURIFICATION.

From the scrubbers the gas charged with three important impurities, carbonic acid, sulphuretted hydrogen, and carbon bisulphide, passes on to the lime purifiers. Of these the two former and all but the last traces of the latter have to be removed from London gas, this last process being known as sulphur purification. Formerly this, the most troublesome process known to gas engineers, has now been reduced to great simplicity, and as the subject is one of considerable interest, a few words upon it may not be out of place.

By the Metropolitan Gas Act of 1860, it was required that not more than 20 grains of sulphur should be contained in 100 cubic feet.

This condition the Companies found themselves unable to fulfil with any degree of certainty, and the matter rested to a great extent in the hands of experts until the year of the coal famine in 1873.

The Phœnix Gas Company very injudiciously raised their price ninepence per thousand cubic feet at a bound, agitations everywhere ensued, and officials were appointed by the Local Authorities to test the gas supplied for sulphur compounds, with the result that many excesses were found and prosecutions resulted.

These troubles directed the attention of engineers and chemists to the question of sulphur purification, with the result that the following method was adopted, viz. the lime boxes were split up into two series, the first being used to absorb the whole of the carbonic acid, while the sulphuretted hydrogen was taken out in the second, and formed a compound with the lime, which alone appeared to have any effect upon the bisulphide of carbon.

Unfortunately the required sulphide of lime was extremely difficult to produce in some works, though the conditions were apparently identical with those in operation elsewhere, and sulphuretted hydrogen when passed freely into a clean lime box, although readily absorbed thereby, could not be relied upon to effect the purpose required. But a very curious condition was noticed in connection with this sulphuretted lime; as soon as the cover of the purifier was lifted it began to heat, and unless quickly removed, charred the wood sieves supporting it.

It occurred to the Engineer of the works to put back some of this, to all intents spent material, with the astounding result that the sulphur compounds were at once reduced by between 15 and 20 grains.

This system of making a sulphide box continued in force until quite recently. A peculiarity of these same works deserves mention as being the cause of the trouble. The exhaust on the foul mains was never below atmospheric pressure, consequently no oxygen in the form of air was mixed with the gas. Experiments have since proved that sulphur purification without oxygen is not practicable, and this fact has long been known to Metropolitan engineers who, by "drawing" regularly from half per cent. upwards of air, have been able to keep their boxes active when a series of four of them is worked in rotation. In further relation to this question, owing to the improvements made in the production of oxygen by Mr. M. Brin, Mr. W. A. Valon has proposed its use instead of air for the above purpose, and the process has already been worked at Ramsgate and other works.

Referring again to the impurities to be extracted, the last of these is the residual sulphuretted hydrogen, and the removal of this is effected by hydrated oxide of iron, which can be used over and over again until saturated with sulphur.

Brief mention must be made of the best disposition of purifying houses. The lime boxes should stand on the first floor which allows of barges, trucks, or carts being brought immediately underneath them, and thereby greatly facilitates the discharge without nuisance of the spent material.

The quicklime is lifted direct to the top floor above, slaked and stored there, and run down shoots into the boxes as required.

Good examples of the above have been erected in London by Mr. John Methven and Mr. Harry Jones.

The oxide boxes should be on the ground level with revivifying floors above, to which the foul oxide may be lifted by steam or hydraulic hoists, spread out, and, when ready for use, tipped down the shoots in the same way as the lime.

Station Meters.

The gas on leaving the purifiers enters the station meters for measuring. These are simply ordinary wet meters on a large scale.

The author cannot too strongly urge upon gas engineers the great importance of correcting their readings to a standard temperature and pressure, but is of opinion that 60° Fahr. is probably too high by some eight or ten degrees.

Gasholders.

The subject of gasholders forms a fitting conclusion to a paper read before an engineering society, since the modern structures are certainly a triumph of constructive skill.

A gasholder, as is well known, is a light wrought-iron vessel floating in a water-tank, and guided by standards or columns fixed thereto.

In some of the earlier structures, which were on a very small scale, these standards were simply cantilevers, T-shaped in section, bolted down at their base to the tank wall, and were without any cross-ties or girders. As the holders increased in size the cantilever standards were disused, and in their place a ring of columns, connected at their top, and in most cases intermediately by horizontal girders, was substituted.

Since, in the majority of cases, there was no diagonal bracing, the bulk of the overturning strain due to wind pressure was transmitted by the radial rollers to two or three columns only; and it was an easy matter for one man sitting on the top girder to cause some of these structures to oscillate several inches when the holder itself was down.

Mr. Paddon added wind ties to the column tops, and was thereby enabled to maintain them in a circle under the distorting influence of wind pressure without depending upon the resistance afforded by the curb of the gasholder. A plan of this bracing is shown in Fig. 14.

The use of tangential rollers instead of radial ones has enabled engineers to obtain the fullest advantage of this increased stability of the framing, and the comparative advantages of the two systems may be seen by referring to Figs. 15 and 16.

A third arrangement has been designed by Mr. George Livesey, and is shown in Fig. 17. Its object is to transmit the thrust of the rollers more directly to the holder, and at the same time to retain the advantage of the tangential type. The modern gasholder, which may be said to owe its inception to this gentleman, and of which such fine examples have been designed by him, is surrounded by a framing so constructed as to form a rigid cantilever, circular in plan, with the tank wall, to which it is securely bolted, for its base.

The largest gasholder in the world is now being built for the East Greenwich works of the South Metropolitan Gas Company, at a cost of 42,000*l.* It will have six lifts, the two inner ones rising clear above the guide framing, and will contain when full over twelve million cubic feet of gas.

In conclusion, the author would mention an ingenious invention, patented by Mr. Gadd, for dispensing with the ordinary guide framing of gasholders. A series of double spiral girders are fixed to the tank wall, and between these work rollers carried on the bottom curb of the gasholder. As this rises it turns on its axis, and the spiral form of the girders maintains it in a level position. This system of guiding the holder from its base, *and at the same time preserving its stability against wind-pressure*, is one that can only be safely applied to small holders, and then, too, with questionable advantage.

DISCUSSION.

The CHAIRMAN proposed a vote of thanks to Mr. Carpenter for bringing before the Society a paper on a subject of such interest. Nearly five hundred papers had been read before the Society of Engineers; and it seemed to him somewhat remarkable, considering how many of the members of this Society were, or had been, associated in one way or another with the manufacture of gas, that such a small number of papers had been read upon that subject. Their respected Honorary Treasurer and Secretary, Mr. Alfred Williams, had told him that evening that, in the year 1855, he had read a paper upon the subject of gas-making, which, however, did not appear in their 'Transactions,' as papers were not printed by the Society in those early days. Mr. Williams, he believed, was one of the first to use wrought-iron columns for the support of gas-holders, by the introduction of which he had been able to bring about a considerable saving in cost. He (the Chairman) had found only three papers in the Society's 'Proceedings' on the subject of gas manufacture: one by Mr. A. F. Wilson, in 1864; another by Mr. H. Gore, in the same year; and one by Mr. R. P. Spice in 1886. Gas-making was a matter which interested them all; they would remember how great an impetus had been given to the subject after the wonderful Electrical Exhibition in 1880 and 1881 at Paris and the Crystal Palace. The Crystal Palace Company had just arranged for another electrical exhibition in the autumn of the present year. This, he thought, was a matter of interest to all gas engineers; because, in order that gas might be kept well to the front, and be enabled to compete with electric lighting, it was necessary that it should be supplied in a very pure and satisfactory form, and at the same time at a moderate price. The meeting would be glad to have the opinions of the many practical men, now present, expressed in the discussion which was about to take place.

The vote of thanks was carried by acclamation.

Mr. CHARLES GANDON said that he agreed with Mr. Carpenter upon almost all the points referred to in his paper; but, at the same time he might state a few of his own experiences. He understood Mr. Carpenter to object to one of the two arrangements of seven retorts, shown in Diagram No. 2, one retort being over the furnace. Perhaps in theory Mr. Carpenter was quite right, but he, the speaker, had used such settings for thirty years or more, and had found them answer very well. The over-heating of the middle retort could be guarded against by shielding it, and such a setting accommodated more retorts for the area occupied than some of the others shown. With regard to generator and regenerator furnaces, he had no doubt that a primary and secondary air-supply to a furnace was theoretically the right thing, on the assumption that in the generator there was first produced carbonic oxide, and that, by the secondary air-supply, more oxygen being admitted to this, perfect combustion should be the result. He had, however, tried two or three of such furnaces, but had not found much advantage from them. This, no doubt, was due, not to a defect in the principle, but to the difficulty of getting ordinary workmen to understand and manipulate them. Ordinary furnaces were, no doubt, extravagant from either too much or too little air being admitted to them; but, taking them all in all, they were the most simple; and they seemed to suit the capacities of ordinary stokers better than more complicated fires. He believed that the system of regenerative furnaces which Mr. Carpenter had devised was a very good one, and he should be glad to hear some particulars as to the comparative economy of it. With regard to mechanical stoking, Mr. West's compressed air stoking machinery had been in use at his works for three winters; and though it worked very well, he was disappointed that it did not effect more economy. The fact was that the machinery in a retort-house was rather difficult to deal with, the air being charged with coal dust and smoke, and a great number of repairs were required. By using this apparatus there was, no doubt, an economy in labour for drawing and charging, but the machinery required much attention and frequent repairs; and he could not say that, on the whole, the saving was very great. He had not had experience of inclined retorts, but it had always seemed to him that the principle was a right one. Coze's system, referred to in the paper, was not new in principle; the chief thing which the patentee could claim for it was that he had discovered the best angle of repose for the charges. He, the speaker, was inclined to doubt whether that angle would always be the same, considering the varying conditions of the coal and other circumstances. He had lately seen a modification of the system, as made by the engineer, Mr Trewby, at the Beckton works of the Gas Light and Coke Company. A shield was introduced into the retort, and the coal was allowed to shoot into the space between the bottom of the retort and the shield, thus securing an even layer of coal. This certainly seemed to be an improvement upon the Coze plan. So far as he knew, no details had been published as to the results of the working of inclined retorts. In connection with retort fittings, Mr. Carpenter had referred to anti-dips. With the ordinary dip pipes, the ends of which were immersed in the liquid in the hydraulic main, the gas was prevented from escaping from the retorts while they were opened for charging, and it had to bubble up through the liquid, which naturally caused a pressure in the retorts, and the liquor in time became replaced by tar condensed out of the gas, which increased the pressure and caused a considerable oscillation. The idea of the anti-dip was to dispense with the pipes dipping into the liquor in hydraulic mains, and thus remove the pressure and oscillation. At his works he had an arrangement by which the communication between the hydraulic main and the retorts could be shut off when the retorts were being charged, and could be worked with or without dips; but although it had worked well for ten years, it did not seem to be of any great advantage, as it increased the cost of the retort fittings, and there was some little danger of explosion. Mr. Carpenter had shown three progressive improvements in exhausters, but, still further, there were now four-bladed exhausters being made. These had their merits and demerits; a four-bladed exhauster certainly gave a more steady gauge—that is to say, it drew the gas from the retorts with more regularity than a two-bladed one. Scrubbers and washers were so mechanical in their action that he did not think there was much to be said in favour of one form over another. The Livesey washer removed tar very effectually, but it gave a heavy back-pressure. The question of sulphur compounds was a very large one. He recollected Mr. George Livesey saying that until the sulphur compounds were discovered the life of a gas-maker was a happy one, but after that time it became a misery. These compounds were still a trouble, although, perhaps, gas-men were better able to deal with them now than they were at the time Mr. Livesey made that remark. He was certain that the expense of removing them, to conform with the ideal standard which had been laid down by Parliament, was not compensated for, and the expense had to be borne ultimately by the consumer. His own company could sell gas at 2*d.* per 1000 cubic feet cheaper were it not for having to remove the sulphur compounds. He had had no experience of the oxygen process, which Mr. Valon had so ably manipulated; and he could not say whether it would enable them to effect the removal of the sulphur more completely. He quite agreed with what the author of the paper had said on the subject of gas-holders. The wind-ties of Mr. Paddon's design were a great element of stability in the framework. With regard to tangential rollers, there was a point which he would endeavour to illustrate by a diagram on the blackboard. Taking the case of a small holder with four standards and the ordinary radial rollers, it would be seen that the pressure of the wind might have to be resisted by one standard alone; but if tangential rollers were used in addition to the radial rollers, the wind-pressure might be distributed over three out of the four standards, and this seemed to be a great argument in favour of tangential rollers. He could not quite agree with the author of the paper in his recommendation to correct the station-meters for temperature and atmospheric pressure. It seemed to him an unnecessary refinement to do so; they might as well say to the consumers, "Although your meter indicates that you have burnt 10,000 feet, yet, according to the corrections, you must pay for 11,000." He believed that he could recollect the time when Mr. Carpenter's company had no station-meters; they simply registered the rising and falling of the gasholders, and then said: "We are using so many tons of coal, and they have made so much gas." On the Continent most elaborate calculations for these corrections were frequently made; but it had always occurred to him that it was a waste of time to do so, as in the end the fluctuations of the seasons would compensate for each other. In concluding, he would like to express his great appreciation of the trouble which Mr. Carpenter had taken in the preparation of his interesting paper.

Mr. W. A. Valon said that he agreed with Mr. Gandon that a setting of the kind which Mr. Carpenter had condemned might be used very fairly so long as the centre retort was properly shielded, although he preferred abolishing the central retort when it interfered with the combustion chamber. With regard to generative firing it was well known to many present that he had had a great deal of experience with it, and he had carried on very hard fighting for two or three years by means of a paper war, he being the first engineer in England who had applied gaseous firing to the whole of his retorts. He thought that the controversy had cleared the air. Gas furnaces might be made of a very simple and economical pattern and still utilise the waste heat, and this should always be done, although it was not so in Mr. Carpenter's arrangement. He did not believe in any central system of heating. He liked every set of mouthpieces to have its own furnace and to do its own work, and he did not believe in any system of firing by which the gas was conducted from one setting to another, or even in having one furnace heating a through set. He preferred a furnace for every set of mouthpieces. If the retorts went through, they should have a furnace at each end for the purpose of distributing the gases evenly in the bed, whilst their temperatures were maintained without loss from radiation by conduction. The difficulty in a central system was in conducting the gas from one set to another. Radiation was very great, and the loss to be made good was so large, that it used up a considerable portion of the gas which could otherwise be utilised for heating the retorts. Experiments, of which Mr. Carpenter was fully aware, had shown clearly how easily the heat was lost by radiation. It was very true that economy was effected by nearly any form of gaseous firing. He believed that those who had tried it would agree that there was a great saving in simply converting solid fuel into gas and using it as Mr. Carpenter indicated, so as to get the heat evenly spread among the retorts, that each one might be properly heated from end to end, and also that the quantity of gas might be properly regulated and applied. This was almost impossible in any system of direct firing. He did not agree with Mr. Gandon that there was any difficulty whatever in firing generator fires. The regulation of the draught would be effected by faced doors. The air ports ought to be set by the foreman or by the manager himself, and, practically speaking, when they were once set, they never had to be moved. The fire was simply built up by the stokers who knew nothing at all about the matter, and they were cleaned out by the man below who knew nothing of what the man above was doing. The air ports ought to remain a fixture. He had never used anything else but a closed hearth. He had done away with the bars, with the result of effecting a large saving in fire bars, and also making it much easier for the man to clinker the fires. He found no difficulty with either soft coal or hard coal, the doing away with the bars was a distinct advantage. With regard to oxygen purification, it was true that he had great interest in it having carried out the initial, important, and very lengthy practical experiments in connection with the subject, the oxygen being supplied by the Brin's Oxygen Company with a view of determining the effect of oxygen applied to lime during the purification of gas. Of course it was well known before the application of oxygen to lime, that it could be used with oxide of iron so as to revivify, to a certain extent, *in situ*. He did not think however that the effects on lime were so well known to metropolitan engineers as Mr. Carpenter claimed, until the experiments which he had the privilege of conducting were fully published, if so, they had succeeded in confining the knowledge to themselves. He had proved beyond doubt that there was no system of air purification either with lime or oxide, which permitted of sufficient being used without seriously depreciating the illuminating power of the gas. If they used as much air as was necessary to give sufficient oxygen to effect the purification properly, the illuminating power of the gas was seriously interfered with, notwithstanding some assertions to the contrary which were demonstrably fallacious.

Experiments conducted alternately with air and oxygen for 16 or 17 months, showed that between the proper quantity of pure oxygen and the same quantity of oxygen contained in air, there was a difference of something like two candles in the illuminating power of 16-candle gas, and he thought that that difference was serious enough for gas engineers to take into consideration. Again, he could not find that by any system of air purification he could entirely oxidise the lime so as to be able to handle it and remove it without nuisance, and this he thought was owing to the difficulty of two operations going on in the purifiers at one time, viz. the separation of the oxygen and nitrogen and the application simultaneously of the former to the work of purification. But by means of pure oxygen they could pursue the purification of gas to the bitter end, and use up every particle of lime that could be used, and put the lime out without any danger whatever of its being the slightest nuisance, or anybody finding fault with it. He thought that that was a very strong point in favour of oxygen purification, and in addition to this space and labour were also greatly reduced, and indeed economy effected all round. With regard to his friend Mr. West's machinery for stoking, he had used it in small works, and in some larger works; and he must say that, in his experience, it made a great saving in labour. He had estimated, and, he believed, quite rightly, that it had caused a reduction of something like *9d.* per ton as compared with hand labour. He had applied it to small works, and Mr. West had himself some little difficulty in the first instance in getting the machinery to work lightly enough for one man to govern it, but at length they got it to do so. The machinery was worked by one man, who also drew and charged the retort, and he did the work very easily. He thought that it was almost needless for him to say to practical men, that if they had hand machinery which could be so easily manipulated, it ought to be introduced more freely into gas making than it had been. In fact, he thought that it was a reproach to gasmen that they had so long neglected to introduce machinery into their retort houses to supersede hand labour. The result of neglecting to do so had been shown to a very great extent in strikes and proceedings of that kind. Strikes could be easily avoided by the proper use of simple machinery. With regard to anti-dips he agreed with Mr. Carpenter that they were rather a snare and a delusion. With regard to the tar being displaced by the liquor in the hydraulic main, that was overcome by balancing the liquor and the tar.

and keeping the column of liquor considerably higher than the tar. This would keep the tar out, and the end of the pipe would always work in liquor. As to temperature and barometer he always corrected for these every morning. But it was only from a desire to know from day to day the volume of gas that they had made. He has pursued this practice for many years; and at the end of twelve months, taking the bulk of gas made from year's end to year's end, he found that if he had not made any correction at all, he would have come to about the same place.

Mr. J. L. Chapman said that he thought that the arrangement of the six retorts was certainly the best form of furnace and setting for small works. The objection which he found to the arrangement of seven, was that the setting was soon stopped up in the nostrils, and these had to be cleared out almost every day to secure proper combustion in the furnace chamber. His experience was that the setting of six retorts gave a large make per ton, and a large make per mouthpiece, and more gas than he used to get from the setting of seven. He had not had any experience of tile retorts, but he had had some with regard to shapes of retorts, having worked round, oval, and D. The D retorts had a great many faults, but they had the advantage of giving a thinner layer of coal in consequence of the flatter surface; he thought that the gas passed away more freely from D retorts than from the other forms. The distillation was more complete in consequence, as he believed, of the thinner layer of coal, and the greater surface from back to front. He entirely disagreed with Mr. Valon with regard to the air purification, and he did not believe that the illuminating power fell to anything like the extent he spoke of. He had had an experience of eight years in the use of the air process at works which were not under the sulphur clauses. He strove, whenever they had the opportunity, to take out the carbonic acid, and he found that air purification gave good results. He had a 12-feet purifier and three 8-feet purifiers, and with the air process he had been able to pass nearly 200,000 cubic feet of gas through per 24 hours, without any difficulty except in the middle of the winter. There was no serious diminution of the illuminating power. As to the construction of gas holders, of course in such matters the question of expense would come in, and after all that was a great one for the gas engineer.

Mr. Joseph Cash, stated that the previous speakers had dealt with many of the questions which might be raised upon Mr. Carpenter's interesting paper, but there were one or two points he could not allow to pass without raising an objection. The first was the form of retort recommended by the author, viz. oval. His, Mr. Cash's, experience had been entirely with round retorts, and he could not allow that form of retort to be condemned without raising a protest in its favour. Round retorts had produced excellent results shown by a production of over 11,000 cubic feet of gas per ton of coal at Portslade, a result he was perfectly satisfied with. Again, the author had shown a number of various types of bridge pipes, all of which he, the author, condemned except one, and the type used at Portslade was one of those condemned, *i.e.* the semicircular type, but with the bonnets placed at an angle of 45° on either side instead of as shown. In his opinion the form of bridge had little to do with the cause for which the author condemned them. The cause was one which had not, so far as he was aware, been previously discussed, and that was the action of the ascension pipe. Experiments made at Portslade showed that the temperature of the gas at the inlet of the ascension pipe was from 450° to 500°, while at the top of the bridge it was only 120°. This showed rapid condensation, and the tar on its way down trickled over the heated cast-iron ascension pipe and was converted into pitch, and so gradually stopped the pipe. He, Mr. Cash, had lately adopted wrought-iron ascension pipes, and they had done away with this trouble owing to the thin wrought-iron pipe parting with its latent heat more readily than the thick cast-iron pipe, and the tar not being converted into pitch, flowed down the pipe and formed a small pool in the mouthpiece, where it is removed before drawing the charge in a specially shaped shovel, and deposited with the coal, and so transferred back into the retort.

As the question of purification had been raised, he might say that he looked forward with great interest to the use of oxygen, as shewn by the results obtained by Mr. Valon. It might be interesting if he stated some results he had obtained in the use of a new purifying material called "Weldon Mud," a bye-product of bleaching works, chiefly consisting of hydrated oxide of manganese. It was a material not much known to gas engineers, but one which they would probably become more familiar with in the future. At present he was using the mud in the catch purifiers at Portslade, and the result of some recent experiment showed that 46 tons of mud purified 380 million cubic feet of gas from the sulphuretted hydrogen given off from the sulphide purifiers. The sulphuretted hydrogen was absolutely removed, not merely in a way that satisfied the usual tests made which would often show a slight stain by prolonged contact, but absolutely. The duty obtained from the mud was six times the amount given by oxide of iron placed in a similar position. The mud can be revivified by air in the same manner as oxide, and the sulphur absorbed by it can be easily extracted, and is of a quality superior to that extracted from oxide.

The mud was also used on another occasion as a sulphide purifier and gave excellent results, varying from four to seven grains of bi-sulphide of carbon. Unfortunately it was exposed to too much carbonic acid, for which it has a great affinity, and the material became carbonated, whereby its usefulness was diminished, but this could easily be avoided. The experiment was valuable as showing that the material is a ready-made sulphide, available in an emergency at an hour's notice instead of having to subject lime to sulphuretted hydrogen for several days to form a sulphide.

When used as a catch-purifier it removed a grain of bi-sulphide of carbon nearly the whole time it was in use. Its other advantages are, that it so perfectly absorbs air impurities that when foul it is inodorous, it gives less pressure than lime and only one-half of that given by similar quantities of oxide, and by using it, a further saving can be effected in that only one catch-purifier is required instead of the two usually necessary.

The only other subject he might allude to, was the arrangement of tangential rollers shown in figure 17; they were new and had the merit of a better distribution of strains upon the supports.

Mr. John West said that it appeared that there was a certain amount of agreement between Mr. Carpenter and the gentleman who had spoken. He approved of the bed of six retorts for moderate sized works, but his practice had been to have the top retorts more closely together. He believed that a semi-circular arch would be much stronger than that shown on the diagram, and he believed that the retorts would be heated much better. The arrangement of sevens, certainly gave a large combustion chamber, and he had put up a large number in that form. With regard to the third form of seven in a setting, he was in agreement with the author. For many years he worked with that setting at Maidstone, and he altered it by enlarging the retorts and using six instead of seven in the same arch. He thus got much better results in every way. He carried the same thing out on a very large scale at Manchester. He liked the eight setting in preference to the nine, as it afforded a better combustion chamber. As to the tens, there was no doubt that the retorts would heat well and afford good results, but the question was whether it was prudent to go up so high. He should like to know what size of retorts Mr. Carpenter advocated. He did not quite agree with him on the question of the shape of the retorts. He, the speaker, believed in D retorts. The weakness of the corners could be obviated by placing a longitudinal tile at each of the corners. He regarded D's as preferable to oval's, although he knew that excellent results could be obtained by either. He did not quite agree with the author as to the generator setting which he adopted, although some of these had been put up at St. Helen's, where he acted as consulting engineer, and they were working admirably; but he contended that more fuel would be saved by both the primary and the secondary air supply being worked on the regenerative system. Mr. Gordon, in referring to stoking machinery, had admitted that such machinery saved a lot of labour, but he had stated that the cost of wear and tear was considerable. Mr. Valon had not said much about wear and tear, but he seemed generally satisfied with the machinery. Those two speakers were not working the same kind of machine. One was working with compressed air, and the other was working with manual power. If one of them did not get as much advantage out of the machine as the other, it was not the fault of the machine. Where the stoking was carried out partly by one system and partly by another, the managers did not seem to know to what extent the machinery benefitted them, but when the whole of the stoking was done by his machinery, they obtained excellent results. The wear and tear of the rakes and shovels employed in hand-stoking ought to be taken into account in any comparison which was made between the costs of the different methods. He would undertake to put up machinery in any large works, and work at less than half the cost of hand labour; and he would undertake that the wear and tear should not exceed 5 per cent. A few weeks ago he found that the whole of the gas, which was being made at a large works with his machinery, until recently was costing only 1*s.* 1*d.* per ton, and now it was costing 1*s.* 3*d.* per ton on account of the general increase in wages all through the country. He believed that his friend Mr. Bush, of Sydney, who used the same sort of machinery as Mr. Gandon, would tell them that the wear and tear was very little indeed, and that he saved 3*s.* 6*d.* per ton by the use of machinery. The cost of the labour there being from 6*s.* to 7*s.* per ton.

Dr. L. T. THORNE said that he had been interested in following the work which had been done in connection with purification by means of oxygen, and also the further experience which Mr. Valon had obtained at Ramsgate and Mr. Belton at Shrewsbury, since they had taken up the oxygen method permanently in their works. There could be no doubt that that method had great advantages over the air method, and also over the old methods which were adopted under the sulphur clauses. Of course where gas managers were not under the sulphur clauses, and the illuminating power did not matter, the whole question of purification was a subsidiary one. Mr. Carpenter had stated that some of the London companies had been getting improved results in purification by drawing in about one-half per cent. of air, but the improvement was nothing like it ought to be if they drew in sufficient air for the full percentage of oxygen required for the process of purification. Some of the speakers, and Mr. Chapman among them, had hinted that a larger percentage of nitrogen was not detrimental to the illuminating effect of the gas, but he thought that that could not be the case. Where there was a large margin of illuminating power, a certain amount might be sacrificed by the nitrogen process, but the scientific evidence which had been collected for years past showed that the presence of a non-combustible diluent must reduce the luminosity of the gas, because the luminosity depended upon the temperature of the flame, and the temperature was decreased by the presence of a non-combustible diluent. He believed that all gas managers fully admitted that to be the fact in the case of carbonic acid. The detrimental effect of nitrogen was not quite so great as that of carbonic acid as its specific heat was rather less. Mr. Valon's experiments had shown that the presence of from ½ to ¾ per cent. of oxygen gave a great advantage in the purification process. Continued experience had shown that from 0·7 to 0·8 per cent. was the best quantity for general use. The oxygen thus employed caused the purification to go on with regularity and improved the reduction of the sulphur compounds. The quantity of the oxygen was not sufficient to burn up the carbon particles which were deposited in the flame, and so reduce the illuminating constituents of the flame, while it was sufficient to slightly raise the temperature, and thus actually increased the illuminating effect of the flame. If they attempted to get the full effect of the oxygen purification by introducing 3 or 4 per cent. of air, the quantity of nitrogen thus admitted would bring about a very serious depreciation in the illuminating power of the gas. Of course if gas managers liked to throw away all the illuminating power that was another matter, but as to the fact of the detrimental results, he did not think that there was a shadow of a doubt. The simplicity of the oxygen process was a point in its favour. The author had mentioned the lime box, the sulphide box, and the oxide box, as used under the London Sulphur Clauses; but there was no doubt that they would all be replaced by the lime box alone, if they were using oxygen; and the great disadvantage which attached to the use of lime in the sulphur purification, viz. the smell was undoubtedly removed by the use of oxygen. He believed that experiments would show gas managers that there were very great advantages in the use of oxygen instead of air, and that the loss of illuminating power caused by the pressure of nitrogen, far more than counter-balanced the advantage of being able to obtain the air for nothing.

Mr. E. B. Ellice-Clark said Mr. Chapman had made the general statement that no serious depreciation was encountered in using air for the purpose of purification. He presumed the assertion was based upon actual results obtained, and therefore it would be very interesting if he would give figures in support of that statement showing the class of coal used, the period over which the experiments were continued, the number of photometrical observations, the illuminating power with and without the air, and the quantity of air admitted. Some three years ago the Company of which he was chairman, instructed Mr. Valon to make a series of experiments on this subject. These observations extended over a period of 18 months, and the result had been placed before the gas engineering profession. As Mr. Chapman's statements contradicted by inference almost every result obtained by Mr. Valon, they must not be accepted unless substantiated by accurately recorded observations giving the data before referred to.

Mr. H. Iago said that he had had a great deal of experience with air purification, and he had not found it to produce a serious diminution in illuminating value. He was now using from 2¼ to 2¾ per cent. of air at his works, and he was bringing his sulphur compounds down to 8 grains, while the illuminating power was considerably over 16 candles, and no cannel was used in the manufacture. With regard to the corrections which had been referred to, one of the principle reasons for them had been overlooked. Gas-works were supposed to make and sell a certain quantity of gas per day. If the standard was lowered, as suggested by Mr. Carpenter, it would account for two per cent. of the leakage with which they were credited. At his works they corrected up to 60. There was a system of mains in connection with the retort work which Mr. Carpenter had not touched upon. It was the one adopted by Mr. Kirkham, the Chief Engineer of the Imperial Company. That was a perfectly dry main. It had a tar box, and the ascension pipe was separated from the gas main by means of a valve. That was claimed to be a very good system, and he thought that the claim had been upheld pretty conclusively. There was actually no pressure on the retorts. Mr. Carpenter had said that he thought it necessary to have short ascension pipes, and then he advocated tens. That seemed rather a strange proceeding. He (Mr. Iago) had sixes and tens, but the tens did not answer. Mr. Carpenter seemed to be right in his condemnation of one particular setting of sevens. The very fact of having to introduce shielding proved that the principle must be bad. As to the use of machinery, he did not think that it compared so well with hand labour under the low rate of wages which prevailed until about three years ago; but the gas companies were waking up to the fact that what was not considered necessary then is quite desirable now. He believed that the success of the air process depended a great deal upon the point at which the air was introduced. He introduced it into the foul gas mains, and exhausted his gas hot. The air got thoroughly mixed, and it acted as a carrier for some of the richer hydrocarbons which might otherwise be deposited; so that the ill effect of the nitrogen was neutralised by its carrying power. This feature was made use of in the oil gas plan. The lower illuminants were made to carry the rich hydrocarbons. Speaking generally, he agreed with Mr. Carpenter, but he must take exception to the large generators on account of the increased cost of labour.

Mr. J. Somerville said that he agreed with Mr. Carpenter in nearly all his remarks, but as regard to the retorts, he certainly preferred the D shape, after an experience of over 30 years, with both rounds, ovals, and D's. He had not found the disadvantages the author had spoken of. He thought that Mr. Carpenter was in the right way with his regenerative heated retorts in the case of large works. The larger the number of retorts that could be heated the better; it reduced the labour and the percentage of fuel considerably. With regard to the settings, the tens, nines, and sevens were very economical of fuel. The question of air *versus* oxygen might, he thought, be summed up very shortly. During a period of from 25 to 27 years he had used from a half to two and a half per cent. of air, preferably one and a half per cent., and the effect produced depended a good deal upon how it was used. The last method which he had adopted was to heat the air on top of the retort benches, to 200° before it was introduced into the foul main, as it then the more readily absorbed some of the lighter naphthas from the tar, and became carburetted air, but in some places, probably, this could not be done. As to Brin's oxygen process it was best in his opinion for gas works where they had a small purifying area, or were cramped for room, to extend their purifiers, and the one great advantage he saw in the process was that such works by adopting it could go on for a number of years without extension of purifying area. It might, however, not prove as economical when used by those who had sufficient purifiers and with capacity enough to use 2 per cent. of carburetted air, heated in the way he had mentioned, when there was no difficulty with the nitrogen. With regard to tangential rollers, which Mr. Carpenter had mentioned for discussion, they caused the impact of a 32-lb. wind pressure strain on the columns to be more equally distributed, on to three-fourths of the columns, instead of only one-fourth as by radial rollers, and their use enabled the engineer to put up at a greatly reduced cost much larger gas holders, instead of the old small 2-million holders costing about 40*l.* per 1000 cubic feet capacity. Holders and tanks, containing 10 to 12 millions, could now be produced for about 5*l.* per 1000 cubic feet capacity. The last they built cost about 7*l.* 8*s.*

Mr. Lacey agreed with Mr. Gandon that more oscillation was likely to be caused by an exhauster with two blades, as in the Beale type shown on the wall, than by those with a larger number of blades. This was due to the unequal displacement at different periods of the revolution of the drum, the gas being pumped at a much greater rate as the slide approached the vertical position.

Another reason for the oscillations in the pressure was the absence of any valve on the outlet, the gas shut in between the blades at the inlet pressure being suddenly released on the blade passing the outlet part. He had "indicated" these exhausters, and the diagrams showed these variations in the pressure clearly. The Beale exhauster was an excellent machine so far as the utilisation of the work put into it was concerned, but if it were not for the practical difficulties of construction, the exhauster with the largest possible number of blades would give the steadiest pressure.

Mr. W. Woodward said that he wished to correct Mr. Carpenter with regard to the statement that settings of eleven retorts had only been used at the South Metropolitan works in the old Kent Road. He, Mr. Woodward, had put up 12 beds of elevens, with regenerative furnaces at Bury. As regarded the question of retort house work he was rather surprised that Mr. Carpenter had not mentioned the conveying of coal. In his opinion this was one of the most important items of the gas works, exceeding in importance that of stoking by machinery. He could not see how a saving of 2*s.* per ton in labour could be effected by stoking machinery. The coal at his works only cost them 1*s.* 6*d.* a ton to carbonise.

Mr. J. F. Braidwood said that he had been working with two settings of inclined retorts for some time past. They were erecting six other settings, and they contemplated extending them. They were placed at an angle of 36°. They were able to charge them with a simple apparatus, even at that great inclination, and they worked very well. He considered that the saving of labour effected by using inclined retorts would be 50 per cent. He could not agree with Mr. Carpenter with regard to short ascension pipes and anti-dips, having used both long ascension pipes and anti-dips for over 11 years, and he hardly knew what it was to have a stopped pipe.

Mr. J. Tysoe said that he, like a previous speaker, had introduced air into the foul mains to the extent of one per cent., and he had not found any diminution in illuminating power. He preferred the D-shaped retort. The difficulty of drawing a retort depended entirely upon the heat which was maintained. He thought there was no difficulty in drawing if a proper heat was maintained, and the charge was properly carbonised. It was contrary to his experience that extra fuel was required for brick retorts. Mr. Carpenter had said that for clinkering a door, the whole width of the firebars was preferable. He (Mr. Tysoe) thought 18 inches sufficient. It appeared to him that the shape of the arch pipe could not possibly have anything to do with the stoppage of the pipes. His opinion was that the cause of the stoppage was to be found entirely in the charging of the retorts. Bad charging led to stopped pipes. He agreed with Mr. Carpenter as to the casing round the washers. He had his placed in a building, but found no advantage therefrom, and intended to case them round before the next winter. He could not agree with Mr. Gandon in his preference for ordinary furnaces. The duration of a generator furnace was very much greater than that of an ordinary furnace. No person who had tried both could have any doubt on that point. He now had at work the latest improvement in Mr. West's machinery, driven by a wire rope, and he must say that it had led to a saving of 50 per cent. in labour. The machine had not been at work sufficiently long to afford information about the cost of wear and tear which appeared to be the principal point at issue. He had no reason to suppose that the wear and tear of machinery in proper working order would be very much more than the wear and tear of ordinary retort house tools. He thought that Mr. West had rightly touched upon the wear and tear of the tools. That item was often missed in the comparison. He agreed with the author that a correction should be made for temperature and pressure, more especially where there were different works belonging to the same company. It was essential that they should all be reduced to one common denomination. The temperature at which the gas entered the meters varied at different works, and the corrected make should be taken for the purpose of comparison.

THE CHAIRMAN said that the author would communicate his reply in writing as the hour was too advanced for him to reply orally.

Mr. CARPENTER, replying to the discussion, said he was gratified at the very excellent discussion in which the paper had resulted, and that there was scarcely any point contained therein but had given rise to more or less elucidatory remarks.

As regards the setting and heating of retorts, he was sorry to find that the Society's esteemed Past President, Mr. Gandon, still retained his liking for what he, the author, felt could not be termed other than an old-fashioned system.

A setting could not be called a good one wherein all the retorts are not evenly and equally heated; and if in any case the "centre," or "bull's-eye," as it is sometimes called, had to be made with a shielding of 5 or 6 inches thick instead of 3 inches, to prevent it becoming overheated or melted, then that setting must stand condemned. Mr. West had probably been in front of more settings than anyone of whom he, the author, knew, and his confirmation of the above view is therefore important.

He was pleased to have Mr. Woodward's correction regarding the use of "elevens," and to congratulate him on his excellent arrangement at Bury, which should reduce the fuel account to a "lowest possible."

Several of those present had spoken of the relative advantages of D's and ovals, while Mr. Cash stated as his experience that working with circular, or "rounds," had given excellent results. The author, nevertheless, could not admit the superiority of the latter; for, well as Mr. Cash had found these forms to answer, it was probable he would have done even still better with either of the former. Concerning the remarks of Mr. Somerville and other advocates of D's, it could only be said as regards carbonising theoretically they are right; practically, the ovals were equally good, and, in addition, possessed the other advantages mentioned in the paper.

It is improbable that those who have thoroughly tried gas furnaces would ever go back to direct firing.

Mr. Iago had spoken of the economy of the multiple-heated settings first introduced by the author at Vauxhall, whereby as many as thirty-five retorts are fired from one gas producer; and it is unnecessary to urge that, with but one furnace to five arches, there cannot be as much loss by radiation as if each arch contained its furnace, while, at the same time, the distribution of the producer gas through each is as easy and perfect as that of illuminating gas in towns. Two firemen and their mates are able to keep 130 through retorts going per twenty-four hours, which the author thinks is a proof that no other system can approach it for economy in labour.

With reference to stoppages in ascension and bridge-pipes, Mr. Cash's explanation of the former trouble is no doubt correct, and for that reason preferably they should be as short as possible, so that condensation may take place elsewhere.

The author said that after a long series of trials, made under similar conditions of working, he had condemned as imperfect the whole of the arch pipes shown in the diagrams with the exception of that shown in Fig. 10B. He had generally adopted the type indicated by this last figure, with the result that "stoppers" were extremely rare.

As regards stoking machinery, he did not propose saying more than to emphasise an important remark of Mr. Iago's—viz. that the eight hours movement has made stoking machinery a necessity. Before its introduction the rate of wages at the Vauxhall works of the South Metropolitan Gas Company was 2⅓*d.* per 1000, a sum which did not give nearly so large a scope for saving as now exists.

Mr. Lacey's explanation of the oscillation caused by an exhauster was not that generally adopted, and deserved the more careful attention as these variations were usually attributed to other causes.

The author observed that an excellent phase of the discussion was the attention given to purifying. To carry this on successfully with lime purifiers, oxygen was a *sine quâ non*, and had been used, mixed with nitrogen as air, in London to his own knowledge for the past seven or eight years at least—perhaps longer; while its use with oxide of iron purifiers dated back over twenty years.

As regards metropolitan engineers keeping this knowledge to themselves, it must be remembered that it was not until lately that other towns troubled their heads much about sulphur compounds.

Dr. Thorne did not believe that the advantages accruing from the use of oxygen as air were nearly so great as when it was used in a pure state; but the fact must not be lost sight of that in the latter case it forms but from ½ to ¾ per cent. of the total bulk of the gas requiring to be purified.

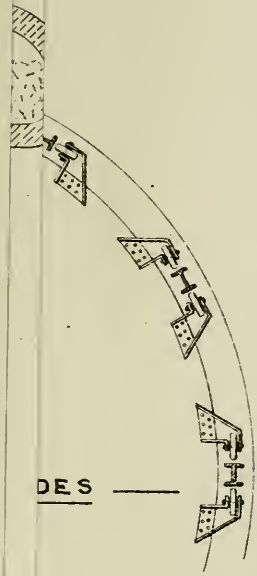
As to the reduction in illuminating power by the diluent nitrogen, since most London companies have now to enrich by means of oil the gas made from common coal, it is a very simple matter to make up for the nitrogen, and obtain the oxygen from the air free.

Though mention is made of "sulphide" boxes in the paper, it ought to be added that the system of using lime only "in rotation," with oxide "catches," is that most generally in vogue in the metropolis, where the conditions as to purity are more stringent than throughout the kingdom.

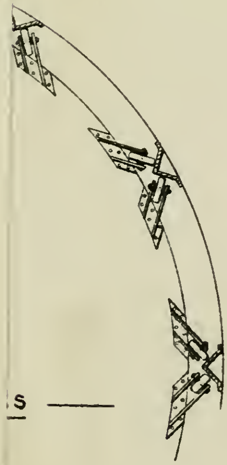
The description by Mr. Cash of the use of Weldon mud was of great interest, though, as the author understands, it is simply in place of oxide. The sulphur compounds are probably absorbed mechanically by it, and the reduction stated would be of little use when the initial quantity generally varies between 30 and 40 grains per 100 cubic feet.

As to the correction of the volume of the gas made for temperature and pressure, if this were done throughout the country, as it is in the metropolis, many serious discrepancies in make per ton and leakage would disappear.

In conclusion, the author expresses his sincere thanks for the very close attention with which the reading of this paper has been followed.



DES



S

Plate 1

BEALE'S EXHAUSTERS

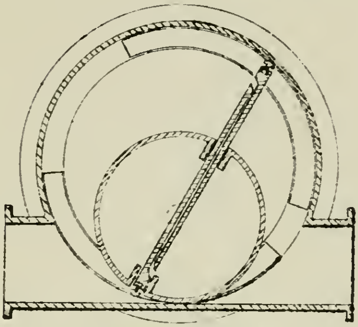


FIG 11. ORIGINAL TYPE.

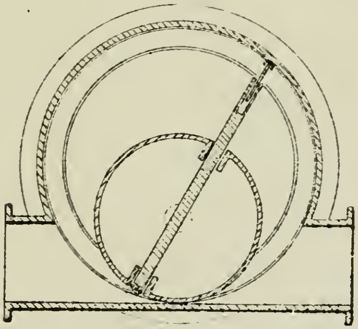


FIG 12. COMPOUND SLIDE TYPE

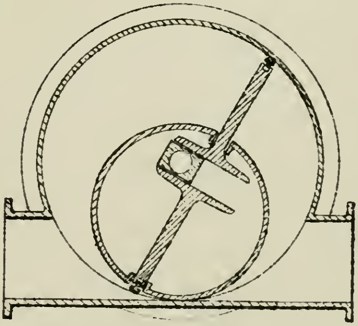


FIG 13. CENTRAL PIN TYPE

Plate.

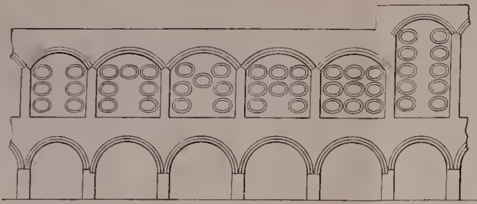
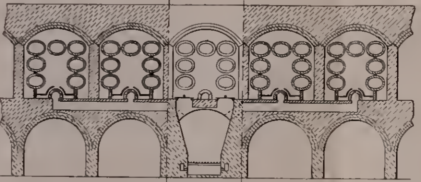
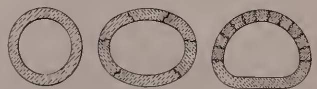


FIG. 2



AUTHOR'S SYSTEM OF MULTIPLE SETTINGS.



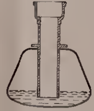
CLAY

TILE

BRICK

RETORTS

FIG 3



HYDRAULIC MAIN & DIP PIPE

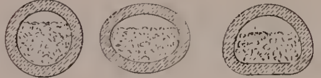


FIG 1

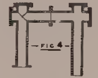


FIG 4

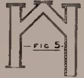


FIG 5

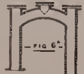


FIG 6^A

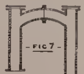


FIG 7

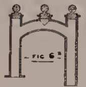


FIG 6^B

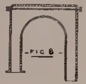


FIG 8

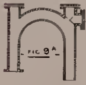


FIG 9^A

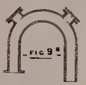


FIG 9^B

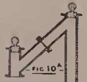


FIG 10^A

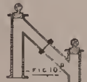


FIG 10^B

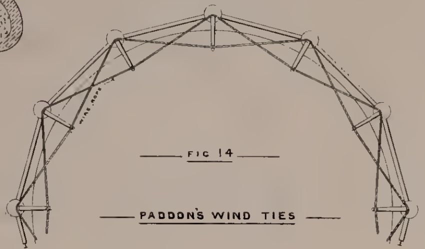


FIG 14

PADDON'S WIND TIES

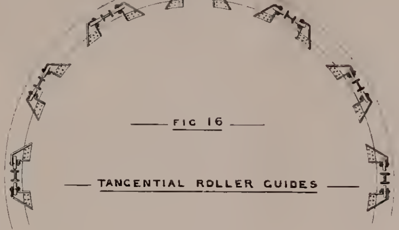


FIG 16

TANGENTIAL ROLLER GUIDES

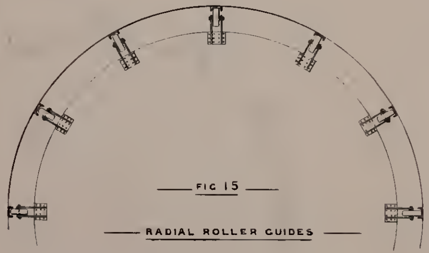


FIG 15

RADIAL ROLLER GUIDES

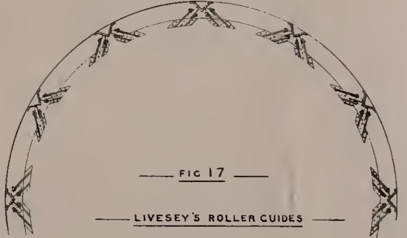


FIG 17

LIVESEY'S ROLLER GUIDES

BEALE'S EXHAUSTERS

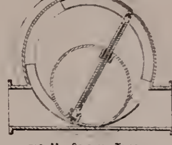


FIG 11. ORIGINAL TYPE

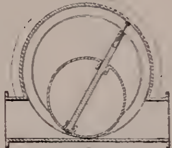


FIG 12. COMPOUND SLIDE TYPE

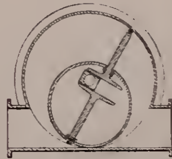


FIG 13. CENTRAL PIN TYPE

E & F.N Spon, London & New York.

June 1*st*, 1891.

W. N. COLAM, President, in the Chair.

PORTABLE AND PIONEER RAILWAYS.

By John Kerr.

To engineers the study of railways is, perhaps, the most attractive branch of engineering, offering, as it does, an almost illimitable field for the inventive faculty, and full scope for the employment of the energy and skill which have raised the character of the English engineer to the present exalted position. Since the introduction of railways the advance of civilisation has been one of leaps and bounds, and, notwithstanding the magnitude of the work accomplished, to the engineer and capitalist there is still left an enormous area of land to be brought under the control of the iron road. If the present rate of railway construction throughout the world is maintained, we are within a measurable distance of seeing every civilised country supplied with a splendid service of trunk lines, with feeder connections, and almost every undeveloped country in the world, with pioneer lines. It may, perhaps, be of interest to know that there is more capital invested in railways than the aggregate capital invested in all other public works.

"Portable and Pioneer Railways" may seem to have little connection with the great railway world; but the author trusts, notwithstanding their apparently small significance, to find sufficient in the subject, from an engineering and commercial point of view, to repay the trouble of an investigation into their economical possibilities.

The author would like, at this early stage of his paper, to disclaim any intention of entering into the debateable ground of narrow *versus* broad-gauge railways. What he has to deal with are in no sense railways to compete with railways proper, but of lines suitable to meet the requirements of factory, mine, plantation, or an absolutely new and undeveloped country, where ordinary lines would be impossible, or, if possible, could only be worked at a financial loss.

Where facility of transport is of importance, and the carrying of a heavy tonnage for short distances arises, a portable railway will prove of the greatest utility, and allow of this class of work being carried out at the lowest possible rate. A moment's reflection will suggest many suitable cases for the application of a portable railway. At first the idea will arise that a railway of a portable character will be utterly inadequate to deal with a heavy tonnage; however, by the distribution of the load on a number of small waggons, the extraordinary amount of work which can be accomplished in comparison with animal or manual power will be realised.

A man with an equilibrium tipping waggon can take a cubic yard of earth on a portable railway a distance of 220 yards, discharge the same, and return in five minutes; whereas it would be good work for the same man to accomplish this task in one hour with a barrow. Taking a labourer's wage at 6*d.* per hour, the result is a cost of ½*d.* per cube yard with portable railways against 6*d.* in the other. Assuming a week's work under both systems, the following results may be deduced—viz. if ten waggons per day are used, 6000 cubic yards can be carried at a cost of 12*l.* 10*s.* on the portable railway, while the same tonnage by the more primitive method would cost 150*l.* In this calculation the working day is taken at ten hours. The capital outlay for the railway and ten waggons would be 110*l.*; and if the work had to be executed in the same time with barrows, the outlay would be, say, 90*l.*, on account of 125 barrows, and further, if—as would happen in many cases—wheeling-planks were required, the total capital expenditure on both systems would be practically the same. The author, in giving the foregoing illustration, may be thought to have given an extreme case; but in plantation work not only can the same economy be found, but in clearing such crops as sugar it is of the first importance to harvest the crop while the cane retains the maximum of price. On many estates, with the use of a portable railway, it is easy to bring in 200 tons of cane per day, thereby reducing the crushing season by some weeks. As a ready means of transport, perhaps no class have so thoroughly appreciated the advantages of portable railways as the sugar-planters. Since the central factory system has been adopted, hundreds of miles of these Liliputian lines are doing valuable service in all parts of the world where the sugar-cane flourishes. One company in Queensland has alone thirty miles of railway and 1500 transport waggons, and in Brazil may be found individual cases of twenty miles of railway.

The use of portable railways is not restricted to earthworks and to plantations, but there are excellent illustrations of their application in the 22-inch gauge line in the great brewery of

Messrs. Guinness & Co., Limited, of Dublin; the 18-inch gauge line at the Woolwich Arsenal, and the 18-inch gauge line at the Crewe works of the London & North-Western Railway Company, which the author has no doubt attracted the attention of many members of this Society during their visit to Crewe last season. If these three important representative concerns have found the advantage of the installation of such railways, the principle is capable of a wide adoption, even if on a more restricted scale, by reason of the requirements of the user being of a more limited description.

For military purposes portable railways are now much used in the construction of fortifications or bringing up provisions and ammunition. Germany alone has hundreds of miles stored in her military depôts.

If time would permit, the author could mention many important canal, harbour, railway, and other great public works in the construction of which portable railways have been extensively employed; but having indicated in a general manner the adaptability of portable railways, their construction may now be considered. As a definition of the term "portable railway," may be accepted that railway of which any section, 15 feet long, is capable of being carried by two men; for instance, sections made up with sleepers, five to each section, i.e. a sleeper for every yard of line would weigh as follows:—

Rails 10 lbs. per yard, rail-gauge 16 inches, 130 lbs. per section.
14 „ 16 „ 180 „
18 „ 24 „ 285 „

The rails used are invariably steel, as this invaluable material gives not only durability, but a much better proportioned section than is possible in iron. The steel used for these little rails should stand the following tests: 39 tons per square inch of tensile strain, 17 per cent. elongation, and 39 per cent. contraction at point of fracture. Figs. 1, 2, 3, 4, 5, and 6 show the standard sections adopted by the author.

It is all important for portable railways that metal sleepers should be used, and again we cannot do better than resort to steel. However, in this instance the quality should be that known as "mild steel," giving, say, a tensile strain of 32 tons per square inch, 20 per cent. elongation, and 45 per cent. contraction at point of fracture. To illustrate the quality of steel used for sleepers there is exhibited on the table a sleeper treated to some severe tests; this sleeper when cold was hammered flat and bent double, and yet there are no signs of fracture. Figs. 7 and 8 show what the author has found to be serviceable sections, wherein the proper degree of rigidity is obtained with the best form for adapting itself to the ballast. The weight of these sections is 10 lbs. and 12 lbs. per yard respectively.

Having dealt with the section of sleeper, attention may now be given to the all important question of the rail fastenings. After much experimenting, the author has found the fastening shown on Fig. 9 not only efficient, but economical in production. Economy in first cost is a very important factor in that which professes to be an economical railway. The outside fastening which is marked "A" in Fig. 9 is a steel dog-headed rivet, which is closed by hydraulic pressure, and the fastening "B" securing the inner flange is composed of an iron bolt with a loose steel angle clip. When the sleeper is cut to the length required, the four holes to be punched are done at one operation, thereby securing absolute accuracy. When the rivetted dog is closed the sleeper is turned out perfect to gauge. On examination, the following important points may be claimed as being attained, viz. :—

1. Extreme simplicity.
2. Quick mounting and dismounting of the line.
3. Perfect security for correct gauge on laying the line.
4. The gauge between the rails cannot vary.
5. The sleepers are easily packed, and
6. Skilled labour for laying the line is not required.

Monsieur Decauville, of Petit Bourg, to whom all credit is due for the important part he has played in the introduction of portable railways, strongly advocates the system of rivetting the rails to the sleepers, but the author is convinced that as no skilled labour is required, or ought to be required, for laying portable railways, it is unnecessary to prepare a rivetted line. No advantage is gained in stability, and the difference between the freight on a railway carried as dead weight, and that paid for by measurement, is one calling for serious consideration. One mile of an 18-inch gauge portable railway, with 10 lb. per yard steel rails, on the author's plan, will have a shipping weight of 22 tons, but if rivetted-up would be charged as for 46 tons.

Having briefly treated of rails and sleepers, we can now consider the method of jointing the rails, and regarding this, experience has proved that, as in the case of ordinary railways, the best joint for portable railways is secured by the adoption of fishplates. Where, however, as sometimes occurs in the use of portable railways, it is necessary to be constantly shifting the line, under these circumstances the adoption of an automatic joint may prove useful and expeditious, but otherwise automatic joints or joint sleepers should be avoided.

On Fig. 10 the author shows a form of automatic joint which is simple in its action, and made sufficiently strong to withstand rough usage. On a sugar estate it is not unusual to have a portion of the railway arranged with automatic joints, and to connect the same with the main line by inclined planes or off-railers, as shown in Figs. 11 and 12.

The points and crossings should be made up in 15 feet sections, so that should it be at any time desired to make a turn-out, it is only necessary to take out a 15-feet section of the railway and replace it by the points and crossing section. In practice it will be found of advantage to have the points and crossings planed from the rails instead of using castings, as these little points and crossings should be made as carefully as those for main lines. In points and crossings the same variety will be found as in ordinary railway practice, you have right-hand, left-hand, and right and left-hand two-throw points, and the same in three-throw points, diamond crossings, four-way crossings, &c.

In practice it will be found of advantage to use turntables as little as possible. Turntables for a portable railway are made either with a wrought-iron bottom plate and a dished revolving top plate, working on a steel pin, or the revolving plate may be of cast-iron. If the line is put down as a permanent one, it is better to use a self-contained wrought-iron or cast-iron turntable sunk into the ground.

It will be impossible to treat in an ordinary paper of more than a few varieties of the rolling stock suitable for a portable railway. One interesting feature of portable railway rolling-stock is the extraordinary proportion of paying, or live load, to dead load. In an ordinary railway waggon the carrying capacity is generally about double its own weight, but with a well-designed portable railway waggon, it will be found generally to be not less than four times.

In the construction of the rolling-stock steel should be used as much as possible. For the under frames a section of channel steel 4 inches by 2 inches, weighing 7 lbs. per foot, will be found a useful standard size. The material to be used for the body of the waggon is best determined by the nature of the work for which the waggon is designed, but in the majority of cases steel will be found to be the most convenient material.

Regarding the best form of buffer much diversity of opinion exists. One is to bend the channel into a circular form at the end of the waggon, or to secure to the headstock a bent iron bar as shown on Fig. 13.

On account of their great strength and lightness the use of cast-steel wheels is recommended. The following are safe loads for wheels of the sizes given below:—

Diameter of wheel..	10 in.	12 in.	14 in.	16 in.	18 in.
Weight of wheel	16 lbs.	22 lbs.	28 lbs.	40 lbs.	56 lbs.
Safe load per wheel	12 cwt.	20 cwt.	25 cwt.	30 cwt.	40 cwt.

To ensure accurate work the wheels should have their naves bored out in a lathe, and fitted on by hydraulic pressure to turned steel axles. As a rule it is not necessary to key-on the wheels except where brakes are used. The steel for the axles should be mild steel with a tensile strain of from 30 to 32 tons per square inch.

Regarding the axle-brackets time will not allow of a consideration of the details of their construction, nor whether they should be fitted with oil boxes, springs, &c., as so much depends upon the nature of the work the waggon is to be applied to. For waggons intended for earthworks, there is no advantage in the use of springs.

Fig. No. 13 shows a very useful type of waggon suitable for contractors, mines, chemical works, &c. These waggons are made in the following sizes, 10, 15, 20, and 27 cubic feet, costing respectively *6l.*, *6l.* 10*s.*, *7l.*, and *8l.* each. The equilibrium-tipping principle is very quick in action, and the waggon when tipped throws the material out at a good clearance. By a simple arrangement these waggons can be made to tip all round. In the design of the waggon illustrated, attention has been paid to the necessity of its being easily taken to pieces, and the wheels and axles and everything being packed inside the box. It is no exaggeration to say that thousands of waggons of this class are in daily use in various parts of the world: to many parts the cost of transport is actually more than the cost of the waggon itself, therefore the importance of securing a substantial waggon capable of easy shipment is very desirable.

Fig. 14 illustrates a type of waggon particularly suitable for sugar estates. Space will not permit of treating of other types of waggons used in the cane fields. In some sugar plantations the canes are cut in long lengths entailing the use of bogie waggons, but the general custom is to cut the canes in lengths of from 4 to 5 feet. The waggon illustrated is 8 feet 6 inches long by 4 feet wide for a 30-inch gauge, and weighs 13 cwt. 2 qrs. A waggon of this type, besides being useful for carrying sugar cane, is capable of dealing with forage, barrels, faggots, &c.

As a rule, manual or animal power is used for operating portable railways, but in some cases where the distances are considerable, locomotives are used for haulage purposes. These have been made with cylinders as small as 4 inches diameter, but for really practical purposes engines of this size have little utility. The author gives the following particulars of three sizes of a four-wheel coupled locomotive, suitable for portable railways.

Diameter of Cylinder.	Length of Stroke.	Diameter of Wheels.	Wheel Base.	Water Capacity.	Fuel Space.	Haulage on Level.	Haulage on 1 in 50.	Weight in Working Order.	Price.	Weight of Rail.
ins.	ins.	ins.	ft. in.	gall.	cub. ft.	tons	tons	tons	£	lbs. per yd.
4	8	16	2 9	70	7	38	8	4¼	350	14
5	10	20	3 0	80	8	63	15	5	425	16
6	12	24	4 0	100	10	93	22	7	500	20

Before concluding this portion of the paper, viz. that devoted to portable railways, the author would like to draw attention to the enormous use made on the continent of these little railways, both for factory and field work. The keen competition which English manufacturers have now to meet, demands that in the various items affecting the cost of production, economies must be more and more effected. The preservation of our trade supremacy depends upon not a point being lost, as foreign competition has now to be contended with in markets which formerly were to this country a practical monopoly.

Pioneer Light Railways.

At the present moment the subject of Pioneer light railways is one worthy of every attention, as we have within the last few years seen the unclaimed portion of the great African Continent divided up between the Powers. It must be satisfactory to those who have the prosperity of our own country at heart, with all its important colonising and commercial power in full vigour, to know that our Government has shown ability to properly safeguard the nation's interests. This enormous African territory is now thrown open to the conquering power of the engineer, but the fertile valleys, and rich mineral treasures which are known to exist, cannot be brought within the control of civilisation unless means are taken to open up the territory. Naturally the question arises, what is the best method to attain this end? In the author's opinion none more potent will be found than in the adoption of Pioneer lines. It is almost impossible for certain minds to realise that a railway to be of any practical use, can be any other than that to which one is accustomed to in this country.

Experience of the successful working of light narrow-gauge lines has toned down a good deal of the prejudice and objection to their adoption. George Stephenson once said "he never had much difficulty in engineering matters, but it was almost impossible to engineer men and overcome their prejudices." Not for one moment does the author advocate the adoption of pioneer lines where the construction of a standard railway of the 3 feet or of the 4 feet 8½ inch gauge can be justified. Instances occur, and more especially in the great African Continent, where he would be a bold man who would attempt at present to justify the construction of hundreds of miles of normal gauge line.

Cheapness of first cost, combined with a large proportion of paying to dead load in working, enables Pioneer lines to be constructed through isolated or mountainous countries, and to return a fair dividend on the capital expended. When the Romans conquered a new country, their first efforts were directed to forming roads, and good roads they made, as the remains of their work in our own island still testify, but to make hundreds of miles of roadway in any country is not only a tedious but a costly undertaking. On the other hand, for the rapid exploration and development of a new country, a railway which can be laid at the rate of eight to ten miles per week, and be capable of carrying hundreds of tons per day at a speed of 12 miles per hour, must surely recommend itself as the best means of accomplishing this end.

The author will now proceed to describe a pioneer railway, of the class he considers as suitable for the requirements of many of the African companies.

The railway should be 24-inch gauge, and laid with steel rails, 20 lbs. per yard, having 2,112 steel sleepers (4 feet 6 inches long over all) per mile, i.e. sleepers laid 2 feet 6 inches apart centre to centre. The examples shown will clearly illustrate the nature of the permanent way, and it will be seen that the sleepers have closed ends to prevent the ballast shifting.

As regards the cost per mile for such a railway, at the present time, when prices are fairly normal, the total for iron-work, including rails, fishplates, bolts and nuts, sleepers and fastenings, would be 450*l.*

On the question of the remaining items of construction, including all earthwork formation and laying the line, the author is of the opinion that 450*l.* per mile is ample. Mr. Salwey, Assoc. M. Inst. C.E., in laying 17½ miles of line of this class in Brazil, found the average cost to be 412*l.* per mile. This amount being arrived at from actual measurement and payment. To show that the work in Mr. Salwey's case is likely to be in excess of the average rather than otherwise, it is sufficient to state that in the 17½ miles there were about 80,000 cubic yards of earthwork, and 12,000 cubic yards of rock-cutting. Basing the calculation upon the foregoing assumption, the cost of 200 miles would be as follows, viz.:—

	£	£
200 miles of permanent way (24-inch gauge) at per mile 450*l.*	90,000	
200 miles construction, at per mile 450*l.*	90,000	
Freight on 11,000 tons, at per ton 1*l.* 10*s.*	16,500	
		196,500
(Or an average of 982*l.* 10*s.* per mile.)		
Expenditure on 13 stations and workshops	5,000	
200 sets of points and crossings, at 15*l.*	3,000	
150 open goods wagons, 11 ft. by 5 ft. by 2 ft., at 25*l.*	3,750	
50 covered ditto, 11ft. by 5 ft. by 5 ft., at 50*l.*	2,500	
20 timber waggons, 11 ft. by 5 ft. by 6 ft., at 25*l.*	500	
5 brake vans, 12 ft. by 5 ft. by 5 ft. 6 in., at 60*l.*	300	
10 composite carriages, 30 ft. by 5 ft. 3 in. by 5 ft. 6 in., at 250*l.*	2,500	
8 locomotives, at 800*l.*	6,400	
	23,950	
Freight, say 10 per cent.	2,400	
		26,350
(Average per mile, 131*l.* 15*s.*)		
Add for up-country freight and for engineering, &c.		65,000
Total		£287,850

or an average cost per mile for line complete of say 1440*l.* In many cases the cost would be less, as the up-country freight in the foregoing calculations forms a very large percentage of the cost per mile.

In investigating the carrying capacity of a line such as that estimated, let it be assumed that the worst gradient is 1 in 50, and that this gradient occurs frequently throughout the route, although of course, it might happen in construction, that at some portions of the line a much steeper gradient would have to be adopted, and to avoid either making a great detour or the execution of heavy earthworks, but in such circumstances the author is of opinion that it would be quite easy to arrange to take up one portion of the train and return with the locomotive to bring up the remainder. On a basis of a 1 in 50 gradient, a train of 50 tons, or say eight vehicles, can be worked, which means a paying freight of 40 tons. On the moderate assumption that only five locomotives are working at one time, and running 100 miles per day, the result would be 500 locomotive miles multiplied by 40 tons per mile, or 20,000 ton-miles in the working day. Or stating the case in another way, supposing 200 tons per day to be carried, and taking 300 working days in the year, this would amount to an aggregate of 60,000 tons per annum. As to the class of merchandise to be carried, it would probably be found to consist chiefly of rich ores, spices, ivory, skins, or other valuable products, capable of paying a good rate of carriage. If such a traffic could be realised, it would give a splendid return on the capital expended, but the question the author has more particularly in view is, to demonstrate that a railway of this class is really capable of performing efficient work, and that it is not a mere toy; also he is distinctly of the opinion that not only in Africa, but in other countries, hundreds of miles of pioneer railways could be laid with advantage, if the prejudices of engineers could be overcome. It should be borne in mind that lines such as are advocated in this paper, after they have paved the way for their bigger brothers, can be transferred further ahead or used for feeders for the trunk lines, and under these circumstances there can be no waste of money in giving them a fair trial. Surely a railway, if even of a pioneer character, is better than no railway. In many cases the railway development of a new country has been seriously retarded by starting lines on an expensive system long before there is sufficient traffic to pay the staff expenses. On the other hand, it would be equally foolish to put down a pioneer line where the traffic or other conditions warrant the construction of a heavy line.

Of all our colonial possessions, India offers one of the best fields for pioneer or feeder lines. This country has an area of nearly 870,000 square miles, and a railway system of 15,500 miles, for a population of more than 200 millions. Compare this with the United Kingdom, having an area of 120,859 square miles, and a population of 38 millions, and which commands the service of nearly 20,000 miles of railway. An increase of 30 millions of inhabitants in ten years is the startling fact presented to England by the Indian census returns. It means that the responsibility rests upon the country of providing work and food for three millions additional people every year in Hindustan alone. There were no abnormal causes at work during the past decade to account for exceptional increase of population; India had a fair average of pestilence, famine, and war, doubtless not to the same extent as in former times, but as much as seems likely to occur in the future. Further, pestilence has been largely and permanently diminished by sanitary reform, and the railway system ameliorates famine by quickly conveying food supplies from districts free from the visitation. To show how much India benefits by her railway system, an Indian correspondent writes as follows on the 4th May, on the subject of the present famine in Madras:—"The gratuitous relief of the destitute is confined to a comparatively limited area of the tracts most affected, and the proximity of the railway and Port of Madras permits of easy importation into the famine-stricken districts, of large supplies of grain, the cheapness of which, as compared with the prices which ruled during previous famines, enabling the ryots to avoid the necessity of resorting to the Government relief works." India is not a rich country, although gifted with many resources. At the present time thousands of miles of light railways could be profitably constructed, and would prove of the greatest assistance in times of famine, by quickly transporting the surplus food held in one district to another. The natives are too poor to contribute much towards the capital, and the Government is averse to giving guarantees, so that the great obstacle in the way of carrying out these lines, is the question of raising the necessary capital. The author would suggest the giving of municipal or provincial guarantees, somewhat on the lines of the Irish Baronial guarantees. As many of the lines would only have small capitals (say from 20,000*l.* to 80,000*l.*), it would be a fitting opportunity for a large corporation to be formed to take over the stock of the different lines, and issue their own debentures at a low rate of interest. A corporation such as indicated, ably administered, would not only be able to earn a good dividend, but would confer a great benefit on the population of India.

In conclusion, the author would like to make special reference to the pioneer line being constructed by the Imperial British East African Company, and to show the effect it will have on the slave trade, nothing can more lucidly express the position, than the eloquent words of Lord Salisbury in a recent address:—"The slave trade on the sea now only exists on the eastern coast of Africa and on the shores of the Red Sea. The districts where the caravans still go, and where it is of great importance that we should stay them, is the tract which lies between the great Victoria Nyanza, a lake—the size of which may be realised from the fact that it occupies an area practically equal to that of Scotland. There is no doubt that the slave caravans crossing that territory may be abolished by one method, if that method can be applied. Sir William Mackinnon is doing his best to lay a railway from the coast to the line of the Victoria Nyanza. Now the peculiarity of a railway, which everyone may have had the opportunity of observing in this country, is that when it is once laid it kills every other mode of locomotion that formerly occupied the same ground. After a railway has existed some time, there cannot be, except as a matter of luxury or caprice, any other kind of locomotion to compete with it. If a railway could exist from this lake to the coast, caravans could no more be employed, as they are employed now, to carry ivory and other produce of the interior to the coast or back again, and it is by these caravans that the bodies of slaves are brought along. Of course, when once a railway existed, caravans would become a matter of antiquity, and if no caravans existed there would be no means of carrying the slaves from the interior to the coast, because I need not say that any slave-dealer who presented himself with a body of slaves to be carried on trucks to the coast would not be very civilly received. Whenever that railway can be made, I believe that the end of the African exportation of slaves will have been attained at the same time, because it will not only, as I explained to you, prevent the passage of caravans from the Victoria Nyanza eastward, but it will place you in command of the valley of the Nile, so that slaves will not be able to cross from thence to the Red Sea. We have done something in our time to aid in this abolition of slavery; to add our stone to the pile which the devotion and foresight of our ancestors began, we now spend large sums on ships and boats to arrest this accursed traffic, with considerable success, but also at great cost, not only to the treasury at home, but also to the lives and health of the sailors who, under that sun, have to give themselves to that tremendous labour. If we are able, instead of taking this expensive and difficult precaution, to pursue the evil to its home and kill it at its root, we shall not only have saved mankind from a fearful curse, but we shall have spared the lives and treasures of our own people, and the lives of the gallant sailors who give themselves to this work."

The author regrets that the limit necessarily put upon the length of a paper has prevented his treating of many details as to the application of portable and pioneer railways, but he trusts that the subject will excite the interest and independent enquiry of many members of the Society.

DISCUSSION.

The PRESIDENT said that he was sure that all would agree with him, that the thanks of the society were due to Mr. Kerr for his very interesting paper, and for the valuable specimens which he had exhibited. The paper would be found to be a very valuable one for reference when it appeared in the 'Transactions.' It was not often that a gentleman whose name was so closely associated with this particular class of engineering could be induced to come before a society and give it the benefit of his many year's experience. The members of the society who visited the Crewe Works last summer must have been very much struck, as the author had remarked, with the application of portable railways for aiding in carrying out the various processes and machine construction dealt with in so large a scale in those enormous works. Many of them had seen the same thing applied at Chatham and elsewhere. He himself had seen a system of the same kind applied recently in a very interesting way at a powder mill. The various houses scattered about the works were connected with the railway, and the passing places were made of hard wood with brass strips pinned to them. From enquiries which he made he ascertained that after laying down the portable railway these works had been enabled to compete with firms whose works were much more favourably situated. He had also seen the system applied to sugar-cane transport, enabling the crop to be collected in a very short time, and large plantations especially could in this manner be profitably treated; the difference in cost of manipulating by mules and by railway, representing the only profit made. They might expect in the near future, he might almost say during the next twelve months, a wonderful and rapid spread of this system of railways. Reference had been made to the vast tracts in Africa awaiting opening up, and he agreed with the author that these could only be satisfactorily developed by means of railways of this kind. For this, if for no other reason, the paper appeared at a very opportune time.

Mr. Henry Adams said that he thought that the paper was important to engineers in general, for they, as a body, were specially interested in everything which served as a pioneer of civilisation, inasmuch as every new construction, if made upon economical lines, called forth other construction. It might appear to an engineer on one of the great English railways, as if the form of railway of which the paper treated was but a toy; but when it was considered that in the districts to be served there were no roads, and that in many cases the cost of freight exceeded the cost of the material, they would see that it was necessary to keep down the weight of the railway to the lowest possible limit. With regard to the tip-wagons which had been referred to, it appeared to him that the author was a little over-estimating the capability of a labourer, and especially of a labourer abroad, when he said that the tip-wagons, to be handled by one man, should be capable of carrying a cubic yard of earth. He (Mr. Adams) estimated that a truck, together with a cubic yard of earth, would weigh 3000 pounds, and that would require a push of 30 pounds on a level. Going loaded and returning empty, at the rate named by the author, would involve an average exertion of 5000 foot-pounds per minute throughout the day of 10 working hours. His (Mr.

Adams) notes of such work showed that 3,120 foot pounds per minute, for eight hours a day, was about a man's usual work in pushing. As to the question of trucks *versus* barrows he thought that trucks propelled by manual labour would only be suitable for long level runs. In that case they would hardly think of employing barrows unless they were in the shape of two-wheeled trucks. He should like to know whether the author in referring to barrows, meant the ordinary navvy's barrow. He believe that the author had not referred to the radius of the smallest curves which were found suitable for the gauge of the railway in question, and for the class of trucks employed. The author spoke of the wheels being fixed upon the axles. He (Mr. Adams) had found that with a 2 ft. 6 in. gauge it was desirable to have the trucks with loose wheels, or, at any rate, with the wheels lose on one side. The section of rails which he had adopted in London on wharf tramways was $1\frac{1}{2}$ inch solid square iron. For a 2-feet gauge line he found that a 25-feet radius was about the limit for a curve, but he had also used flat sheets of cast iron, upon which the trucks could be skidded round in their own length. It had been suggested to him that he should use some of the side tipping trucks for transferring coal from the wharf side to the interior of the wharf, but with a desire to avoid transhipment from the tub into the truck, he arranged a sort of trolley for the tub to be landed upon. The trolley might be taken as a truck-frame upon wheels, with the coal tub resting upon it at the trunnions of the bale. The bale ends, instead of being of the ordinary shape, were widened out into the shape of a flat V, to rest in the V's of the trolley, and keep the bale vertical. The tub was held in the ordinary way by catches or dodgers on each side of the bale; one of these catches being thrown up the tub could be tilted upon the trunnions in the V's, so that the material which it contained was shot out. When the tub was landed upon the trolley, it could be carried to any place where it was wanted without transhipment, which meant breakage. The author had remarked that 13 stations and workshops could be erected for 5,000*l.* This estimate reminded him of the railway station that was first erected at Jarrow. He believed that it consisted of a single plank to stand on, and the station-master, who combined all offices, brought the tickets in his pocket when the train was expected.

Mr. F. H. Gill said that, having had about 14 years' experience in the manufacture of portable and pioneer railways and plant, he had been very much interested in the author's paper, but he thought that there were several of the details of the system described which might be somewhat improved. For instance, in his experience he had found that it was better to employ a sleeper of the corrugated type for portable lines and not a trough sleeper, as the former enables the easy removal of the line at will, whereas the latter was apt to set fast in the ground owing to the form of the sleeper, and was therefore sometimes difficult to remove. He was decidedly of opinion that a sleeper under the rail joint was of great importance on a portable railway; in fact, he considered it was absolutely necessary. He had always found that the joint was the weakest part of a portable railway; for a light fixed pioneer line, however, nothing could be better than the ordinary fish-plate joint. With regard to the Decauville system it was well known that one of the advantages claimed was, first, that on arrival at its destination it was ready for immediate use, whereas the class of portable railways described required to be mounted or bolted together, and that operation in some instances, entailed considerable loss of time and expense. It was quite true, however, that as a set off against the disadvantage of the latter, the Decauville line was shipped as measurement goods, and the freight was consequently heavy, whereas the portable line described by the author was carried as dead weight at a considerably less cost. In fact, the rails were often taken very cheaply by the shipper, as they form good ballast. It was open to question which of the two systems had the advantage upon arrival at its destination. From his experience he thought that the system described by the author might really be considered the best, and, in the long run, the cheapest. What however was required, was a system combining both these advantages. He had had some considerable experience in light pioneer lines. The first section was one of 66 miles, which was laid with 19-lb. rails to a gauge of 2 ft. 6in. The locomotives weighed eight tons each, and ran on six wheels, four wheels coupled and hauling two bogie wheels. This line had been worked very successfully for many years, and had been extended to 86 miles. It had, however, been found advisable to adopt some heavier rails on account of the great increase in traffic. The lighter line which was originally sent out was now being used as a feeder to the main, or line laid with the heavier rails, which weigh 30 pounds per yard. The line had carried a considerable traffic, and he was told had paid a clear dividend of from 7 to 10 per cent. on the outlay, as the same, however, had been a private enterprise, no official data was forthcoming. As to tip waggons he thought that one of 20 cubic feet was as much as a man could work satisfactorily. He regarded a large number of small waggons as preferable to a small number of large waggons. He was sorry that the author had not gone into the matter of curves and crossings, as that was one of the most important questions on light lines. He had found that they could get round curves of about 15 feet radius, with a wheel-base of about 2 feet 3 inches. He also was of opinion that it was advisable that the wheels at one end of the axle should run loose. In fact, he was an advocate for all the wheels running loose on the axles of portable railway plant.

Mr. **Henry O'Connor** said that he had hoped that the author would mention some of the overhead systems which were in use in America for the light feeder lines. He was interested in one, which was not yet fully patented, where the weight would amount to about 12 cwt. per 15 foot run. It would require the fixing of about 20 bolts to fit it up on the ground, and a few cubic feet of foundations in every 15 feet to afford surface for it to stand upon. No piece would weigh more than from 150 lbs. to 200 lbs. It would all travel as dead weight and not by measurement. With regard to curious stations, many years ago he saw a drawing of a station at Hereford, consisting of a hollow trunk of a tree.

Mr. E. E. **Glaskin** said that the trucks, which he had been in the habit of employing, were constructed for a cubic yard of earth, as that size had been found to be most useful. It seemed to him that they could not devise any one system of railway which would be suitable for all the varying conditions likely to be met with. The respective claims of standard gauge and narrow gauge, resolved itself into one of first cost and economical operation. The difference between the cost of constructing a standard and narrow gauge was very slight under general conditions, but the cost of operation per ton per mile was about 50 per cent. in favour of the standard gauge; for the reason that whilst the number of train hands employed, and the coal, &c., consumed, was about the same per train in the narrow gauge as in the standard, the freight carried was only half, making the cost per ton per train mile nearly double that of the standard gauge. To this has to be added the cost of transfer by breaking bulk from narrow to standard gauge. The cost of maintenance of track was the same in both cases, and the cost of construction merely meant the deduction of one to one and-a-half feet from the total width of embankment or road-bed which, when high or deep, would form a very small proportion; the difference in length of the ties would not reduce the price, and the bridges would cost the same unless the foot ton was reduced. As regards the suggestion that a narrow gauge should be a pioneer to the standard, it should be remembered, that to widen an embankment it must be stepped before filling at a cost equal in many cases of half the embankment, that the birms would have to be made into the old ditches on each side, and that new ditches would have to be cut; all the culverts broken and reconstructed, all over bridges destroyed and rebuilt, and curves in many cases re-located; the platforms of stations, turntables, &c., would have all to be torn up and replaced, the ties thrown away and replaced by new, and the whole of the rolling stock relegated to the junk shop. There are, however, conditions where a narrow-gauge is economical, viz. in mountainous regions or among foot hills of the high plateaus, when very sharp curves only can be worked in at a moderate expense, or for workshops, mines, and small contracting. Except under extraordinary conditions, such as above mentioned, the best economy in his experience, for previous railroads, is standard gauge substructure, and light rails and light rolling stock, all of which can be continuously worked into further extension, for the road-bed as a rule does not equal the cost of the rails and fittings; and as the road-bed is permanent, whilst the rails are temporary work, the change should be made and contemplated in the temporary alone. He, Mr. Glaskin, gives this as his experience after having had to deal with both systems, and also to convert narrow into standard-gauge lines.

Mr. Stephen Sellon said that he understood that the paper was simply given to them as a means of affording information respecting the cost of a pioneer railway in a district where the funds would not admit of anything but a cheap and light railway. He wished to make one or two remarks more with a view to getting a reply which would add to his own information than by way of criticism. Mr. Kerr had mentioned 412*l.* per mile as the cost of a line laid down in Brazil; and he stated that in a length of 17½ miles there were some 80,000 cubic yards of cutting of soil, and 12,000 yards of rock. Allowing the ordinary price for the excavation there would be only about two or three thousand pounds left for the material of the 17½ miles of line, or about 130*l.* a mile. He thought that there must be some error unless labour was very much cheaper in Brazil than in England. With regard to the finding of money for the construction of a railway of the kind described, Mr. Kerr had suggested that a guarantee should be given by districts where there were baronies, as in Ireland, either with or without Government assistance. He, however, considered that in cases where guarantees were given, railways of a more substantial character than those suggested by the author should be constructed. They all knew the disastrous effect of a baronial guarantee. The introduction of light railways into Ireland under the system of a baronial guarantee, was tried in

1883, but was an absolute failure, and was the cause of large sums of money spent in promotion being absolutely wasted. Few financial people would look at a two per cent. baronial guarantee, although there was a two per cent. Government guarantee at the back of it; whereas a three per cent. direct Government guarantee would have been easily financed, and the result would have been more economical. He did not approve of the application of railways such as proposed by the author for a large country like Africa, which required to be opened up. Good and solid railways were required for the development of such a country, and the enterprise was more one for the Government, or for individuals backed up by Government guarantees. He was afraid that narrow-gauge light railways could never be satisfactory feeders for railways having a different gauge, because it would involve transhipment of the traffic at great expense and inconvenience, and this was the opinion expressed by Sir James Allport, in the late Royal Commission. At the same time he must heartily thank Mr. Kerr for his paper, for he believed that when it appeared in the 'Transactions' of the Society, it would be valuable for reference to engineers who had to construct railways of the class to which it related.

Mr. ARTHUR RIGG said that he did not profess to know very much about lines of the sort described in Mr. Kerr's paper, except that he had travelled many thousands of miles over narrow-gauge railways, such as the Rio Grande in Colorado. This was a very interesting example, occupying about two days to traverse. What the curves were he did not know, but they were very sharp, and he had got safely round them, although sometimes when approaching one it looked as if he had reached the end of the line; and he confessed to feeling a great sense of insecurity, as the carriages rocked like a ship at sea while traversing these curves. With regard to Africa, it appeared to him that the first thing wanted there was bridges over the rivers, and that if they had them they could get along in spite of the bad roads available. The last speaker had advocated Government making great trunk lines for Africa; but Government was, after all, only an agency which already taxed the people most unmercifully, and if they took up the railways the people would have to be still further taxed for the purpose of creating a huge mismanaged monopoly. As it might be interesting to the meeting, he would describe an early specimen of such a line as Mr. Kerr proposed as used in slate quarries in Wales; it might compare with the much further developed system he had now brought forward and what was done in previous times. The rails were simple round bars of $1\frac{1}{2}$-inch wrought iron, about 6 feet long, tapered and turned sharp over at about 4 inches from each end. These ends then fitted into cast-iron sleepers provided with two sockets at each end, like the handles of a pair of scissors. There was no difficulty in making this rude and simple joint between two contiguous rails, and this rough system was found to make a very good track, and one that could be curved or shifted as required. He supposed it to be one of the earliest form of portable railways extant.

One point which struck him in travelling over the Rio Grande Railway was that the cars measured 8 feet 2 inches in width outside, although they were carried only by a 3-feet gauge railway. All such narrow-gauge railways seemed to him to err on the side of having the carriages too great in width. In Burmah a difficulty had been found in consequence of the wild elephants amusing themselves by pulling up the line. He did not know whether the same thing would take place in Africa, for wild elephants are not yet extinct in that continent, although probably they soon will be if "sport," as it is called, is not to some extent checked. He was sure that they were very much obliged to Mr. Kerr for bringing this subject forward, and they must wish him success in his tramways in Africa, or any other part of the world.

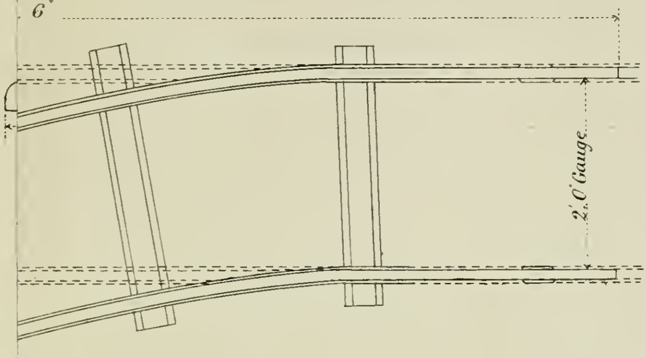
Mr. W. P. Morison said that he quite agreed with Mr. Kerr in thinking that prejudice was the chief difficulty in the way of light railways. There were many instances, not only in new countries such as Africa and Burmah, but even in England, where they would be of great service. There was a difficulty in the matter of the cost of works, but that must depend entirely upon the features of the country. In mountainous districts and in the development of minerals and other products, gradients very much steeper than one in fifty, which Mr. Kerr had selected as the ruling gradient, would be called for. Even to follow the roads of this country in some districts a gradient of one in fifteen might be required. In such a case considerable power would be necessary for taking heavy traffic, and the weight of the permanent way would have to be increased. In a mountainous district great cost would be occasioned not only in earthwork, but for bridges in crossing ravines and rivers. Mr. Kerr seemed to ignore wooden sleepers altogether. He should be glad to have the experience of the author or any other gentleman as to the efficiency of wooden sleepers. He had with him a sketch of a light line which was laid by his firm about two years ago, and which had worked very satisfactorily at a colliery. It had a 56 lb. rail carried on wooden sleepers 2 feet 6 inches apart. A wrought-iron sole plate was used on the sleepers in the ordinary way for taking the bearing of the rail. He believed that it was usual to employ a sole plate, but he should be glad to learn whether such small rails as 56 lbs. would stand and work satisfactorily without the sole plate.

Mr. KERR in reply said that in speaking of the work of a navvy he had referred to a strong English navvy. It would be generally found that a foreigner was not capable of doing half the work. The case that he had given was from his own experience, and he had taken the comparison of a strong man working with an ordinary barrow. He had seen the work being carried on with barrows and waggons, the waggons being such as he had indicated. Those who had had any experience in using a portable railway continued to use it when they had once started. This country was very far behind any other European country with regard to such railways, and in comparison it was surprising to see the extent to which they were used everywhere else. As to the question of curves, the necessarily limited time permissible for the reading of a paper would not allow of this part of the question being treated as he would have liked. With regard to the use of a square iron bar with curves, he believed that they would not be able to get waggons to travel round with such a form of rail, as well as they did with the form which he had illustrated. He had found no difficulty in working round 25-feet curves with a 2-feet gauge without the wheels being loose. Loose wheels were not necessary with ordinary curves, but there was an advantage in them when dealing with very sharp curves such as 10 feet or 15 feet radius. Of course, extreme cases could be provided for. As to the stations the cost, including the workshops, came to about 400*l.* apiece. There were not many luxuries wanted in the wilds of Africa. The inhabitants there were content to live in tin-lined packing cases. In many cases a very small sum of money would provide all that was required. As he had already remarked there was a difficulty in getting people who were considering portable railways to take their minds off a railway proper. They could not realize a railway station less than one something like St. Pancras. Such stations were very nice in England, but they would be "white elephants" in Africa. With regard to Mr. Gill's remarks, if the work was properly done in this country there was very little difficulty in fitting it. On account of the great saving in the first cost it would almost pay to send out a first-class Westminster engineer to do the fitting. He could hardly reply to Mr. O'Connor, for that gentleman had not indicated the kind of railway to which he referred. As to the claims of narrow gauge *versus* broad gauge, he the author, had distinctly stated in the paper that he had nothing to do with that debatable question. It did not affect the railways with which he was dealing. Of course, any country which could afford a broad-gauge line should certainly have one unless there were physical difficulties which prevented their doing so. As to the remarks of Mr. Sellon, he, Mr. Kerr, was sorry that he had not made it quite clear to Mr. Sellon that in speaking of the railway in Brazil the amount given as the cost of construction had nothing to do with the permanent way material and referred only to the earthworks. The subject of the Irish baronial guarantee was one which he happened to know something about. The failure of the guarantee was distinctly political. There was a period when nobody wished to have anything to do with that most distressful country. A lot of lines were authorized, and would have been carried out had this not been the case. The Government was now carrying out many of the lines, although he was afraid that some of the promoters would not earn the profits they expected.

Mr. Sellon said that the Government were now giving a direct guarantee.

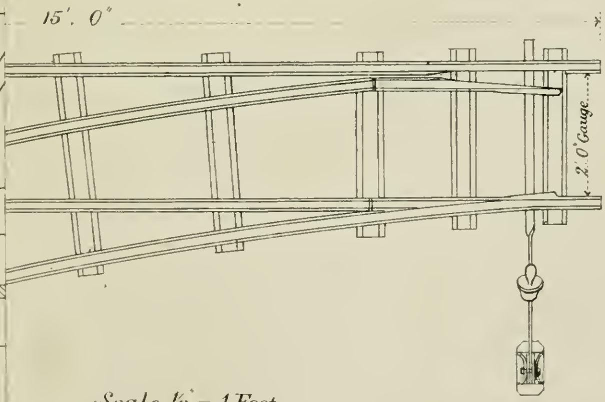
Mr. Kerr said that was so, and rightly. As far as Africa was concerned no one could wish more heartily than he did to see the large territories provided with main lines; but if the various companies waited till they got millions of money to construct such lines the development of the country would only be talked about for many years to come. The lines which he had described were intended to take the place of roads, and to enable the country to be quickly developed. Lines of this character would be quite suitable for many years to come for the districts which were dealt with; and when they had done their part and paved their way for main lines, which he believed would be bound to come if the country was worth anything, the pioneer lines could be moved farther ahead. It might be a hundred years before Africa had its main lines. In the meantime it would pay to have a railway which would not cost more than 1500*l.* a mile. Mr. Rigg had referred to the Rio Grande railway. That narrow gauge line had done its work, but the railways which they had been discussing that evening were not at all like it. The particulars which Mr. Rigg had given with regard to the early portable railways used in the Welsh slate quarries were very interesting. Such lines had done their work remarkably well, but of course they were primitive. Mr. Morison had asked a question about timber sleepers. He (Mr. Kerr) was in no way prejudiced against them. Timber sleepers might be used in all cases if a supply of good timber could be obtained. Timber sleepers were not to be surpassed, but in many districts they would be dearer than the sleepers which he had described, and in some countries they would be destroyed by the white ant. In India a difficulty of that kind had been found. But if timbers of teak or some similar hard wood could be got, nothing could surpass them even in a tropical country for a line of the class with which they had been dealing. He would by no means say that nothing but steel should be used. If timber could be obtained economically let it be used.

Plate 1.



Scale ¾" = 1 Foot.

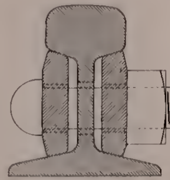
Fig. 11.



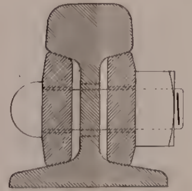
Scale ½" = 1 Foot.

Fig. 12.

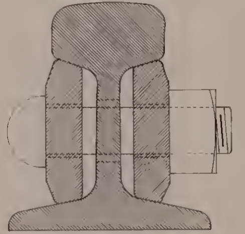
SECTIONS OF STEEL RAILS. FULL SIZE.



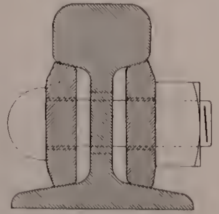
10 lbs. per yard
Fig. 1.



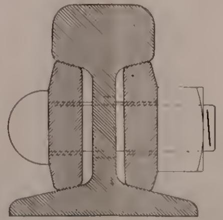
12 lbs per yard.
Fig. 2.



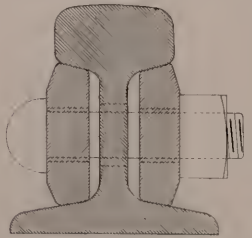
18 lbs per yard.
Fig. 5.



14 lbs. per yard
Fig. 3.



16 lbs per yard.
Fig. 4.



20 lbs per yard
Fig 6.

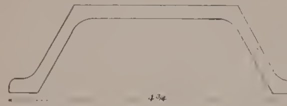


Fig 7.

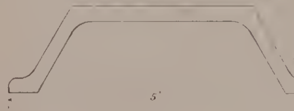


Fig. 8.

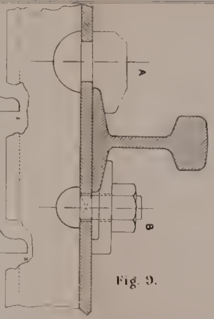


Fig. 9.

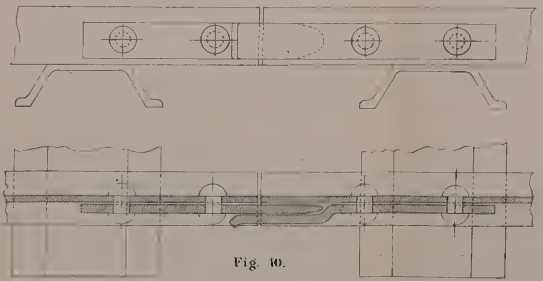
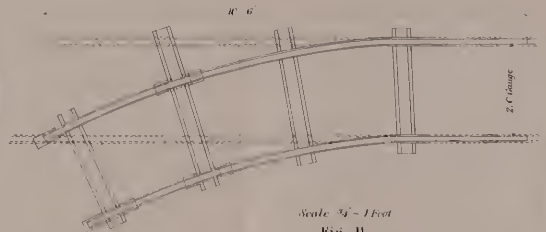
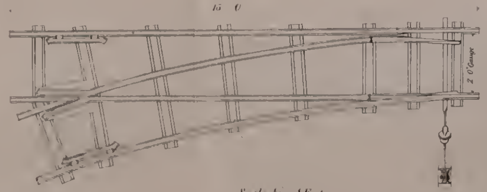


Fig. 10.



Scale ¾" = 1 Foot
Fig. 11



Scale ½" = 1 Foot
Fig. 12.

F & F N Spon, London & New York.

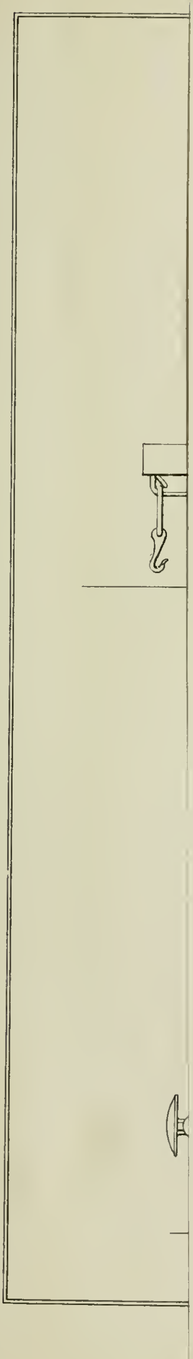


DIAGRAM No. 6.

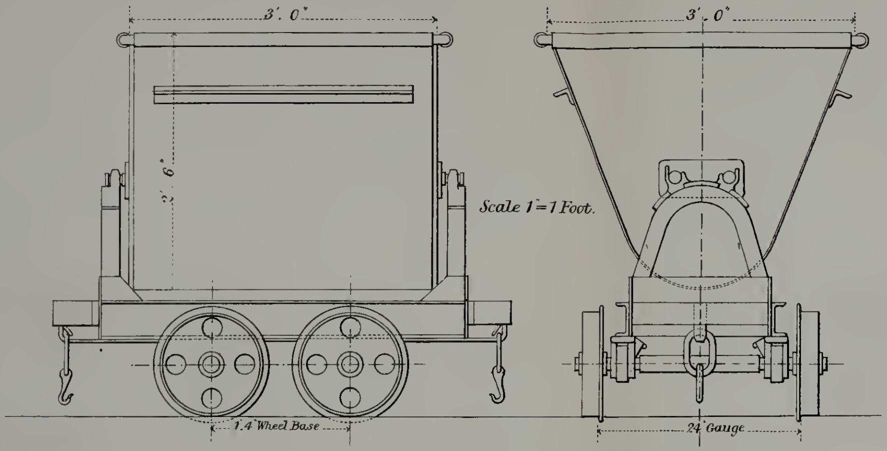


Fig. 13.

DIAGRAM No. 7.

Scale ½ = 1 Foot.

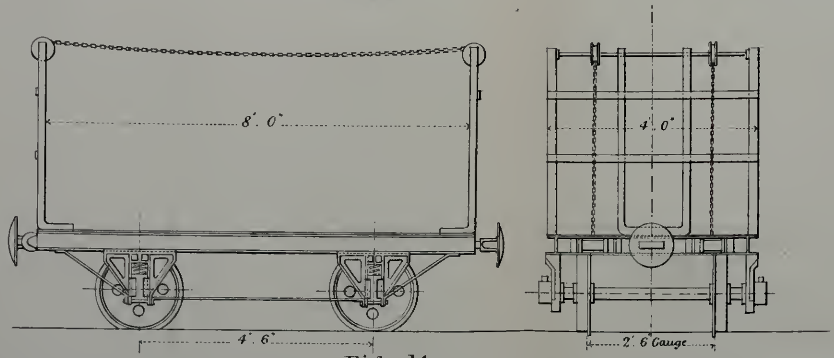


Fig. 14.

E & F.N. Spon, London & New York.

VACATION VISITS.

During the summer and autumn of 1891 the following visits were made :—

On the 17th June the Linde British Refrigeration Company's ice works, at Lower Shadwell, were visited by the members, who were most courteously and hospitably received by the directors and officers of the company. After being entertained at luncheon, the party was divided into sections and taken through the various departments.

These works, which are said to be the largest in Europe, if not in the world, were completed in 1889, and are capable of producing about 120 tons of ice per day, and of storing 500 tons of frozen meat. In the boiler-house are three Lancashire boilers fitted with Bennie's mechanical stokers and a Babcock & Wilcox economiser for heating the feed water. The steam generated in the boilers is not as a rule employed directly for the steam-engines, but is condensed in a distiller, and in condensing produces secondary steam which drives the engines. The water from the condensed steam is cooled and used for the manufacture of crystal block ice. From the boiler-house the engine-room was entered. Here there are two horizontal single-cylinder jet-condensing Sulzer engines, driving four double-acting compressors on the Linde system. These compressors have a total capacity, at normal speed, equal to the hourly production of about seven tons of ice; but part of this power is used for cooling the stores, so that the actual ice-production is about five tons per hour. The condensers for condensing the ammonia are above the engine-room. They are six in number, and the cooling water is obtained from the river, though it is intended to put up a re-cooling apparatus on the roof, so as to enable the same water to be used over and over again. The electric light machinery is also in the condenser room. The ice is made in two large tanks, one of about 90 tons capacity, and the other about 70 tons. The blocks are of two sizes, one weighing about 2 cwts. and the other about 1 cwt.

A large portion of the ice goes to supply the fish-carrying steamers of the adjoining wholesale fish-market, and is crushed and conveyed direct from the tank-room into the ship's hold by means of a continuous screw and shoot. The remainder is delivered to the street by an endless chain, on which the blocks travel from the rear to the front of the building, and by trolleys carrying about 10 cwts. of ice, which are run on to a platform and lowered to the level of the vans in the street. The platform and empty trolley are raised to the first floor by the action of a balance weight.

The meat stores are in the basement, and are cooled by means of pipes on the ceiling as well as by a current of perfectly dry cold air. The extraordinary dryness of the atmosphere is one of the valuable features of the system.

The meat is mostly received from barges coming alongside the river frontage, but sometimes also from the street, and the delivery of the meat takes place by means of hydraulic lifts.

On the same day a visit was made to the City and South London Railway Company's depôt at Stockwell, where the whole of the plant for generating the electric current is situated, and consists of three Edison-Hopkinson dynamos, manufactured by Messrs. Mather & Platt, of Manchester. Each machine is capable of generating 450 ampères at 500 volts, and is driven by a vertical compound engine constructed by Messrs. Fowler & Co., of Leeds. These engines indicate up to 400-horsepower.

The high-pressure cylinders are 17 inches diameter, and the low-pressure 27 inches; the stroke is 27 inches, the motive speed 450 feet per minute; and the steam pressure 140 lbs. per square inch. The fly-wheels are 14 feet diameter and 29 inches broad, driving the dynamos at 500 revolutions per minute. The current from two machines is capable of working the line at any time, leaving the third in reserve.

The hydraulic machinery for working the lifts at the various stations is in the same engine-house as the electric plant, and consists of three 100-horse power engines and pumps which deliver into an accumulator at 1200 lbs. pressure. Two engines are required to do the work, and one is in reserve.

The steam is supplied by six Lancashire boilers, 28 feet by 7 feet, fitted with Vicar's mechanical stokers, and set on Messrs. Sivet's improved principles for the prevention of smoke.

On the 22nd July an extremely interesting visit was made by a large party of the members to the School of Military Engineering at Chatham, where they met with a most courteous reception, and were conducted over the various schools, &c., by officers in charge of each department.

After inspecting the Geological Museum and various relics of the late Major-General C. Gordon, the party was entertained at luncheon at mess by the Commandant and Officers of the Royal Engineers, and afterwards the Schools of Fortification, Surveying, Tactics, Construction, Printing, Lithography, and Photography; the Model Sheds, Mechanical Workshops, R.E. Park, Field Works, Siege Batteries, Treble Sling Bridge, and the Sub-marine Mining Establishment were visited.

In addition to this there was witnessed a series of experiments in the penetration of the magazine rifle, the arrangement of land mines, the demolition of rails and stockades, and the explosion of submarine mines, which had been specially arranged for the occasion, and excited much interest.

On the 24th September, the last two visits of the season were made, and were to the Nunhead and Shortlands Railway Works (in progress) and to The Crystal Palace District Gas Company's Works.

The members were courteously received, and conducted over the works of the Shortlands and Nunhead Railway by Mr. A. G. Drury (resident engineer) and Mr. J. Blue (contractor's engineer).

This line, now in course of construction, commences by a junction with the L. C. & D. Railway Company's main line at Shortlands station and terminates by a junction with their Greenwich branch at Nunhead Junction.

The object of the line is to develope some of the estates through which it passes, and which will become valuable residential properties, the owners of these estates being among the chief promoters of the railway. It will also give the L. C. & D. Railway Company, who are under an agreement to work the line, an alternative route for their main line traffic into the metropolis, *viâ* Nunhead Junction and the South London Line.

For a surburban railway the country passed through is very open, the only building property actually taken being at Catford, yet the number of bridges is considerable, averaging about five per mile, which is mainly due to the number of bridges erected for the accommodation of the landowners in laying out their estates. All the bridges will be of an ornamental character, and the slopes of the cuttings and embankments, from Shortlands through Catford, will be planted with shrubs and trees.

Amongst the works are included three bridges over existing railways, two short brick viaducts, and a retaining wall in Catford, besides other public road and accommodation bridges.

The bridge over the South Eastern Railway, near Catford, will consist of two N truss girders with a skew span of 113 feet each, with underhung cross girders and rail bearers. That over the London, Brighton, and South Coast Railway, at Brockley, will consist of three girders 110 feet span each, of a type similar to those just mentioned, the centre one being between the two lines of rails. The floor in this case will consist, as the headway is limited, of troughs built up with angle bars and plates.

In the case of bridges carrying roads over the railway, the superstructure consists of girders and jack arches, except in three cases, where headway is limited and longitudinal built trough flooring has been used, supported by a transverse girder on columns in the six-foot way.

In the cases of road bridges under the railway trough flooring will also be extensively used on account of the limited headway in most instances. This form of construction also enables the floor to be made perfectly watertight, and the transverse sleepers lying in the troughs being surrounded with ballast, the sound of passing trains will be deadened as much as possible. These bridges have all a clear span of 40 feet at least, and in some instances where the span is greater, columns standing on the curbs of the footways, are being introduced to lessen the weight of the girders and to improve the appearance of the structures.

Steel is being used for the bridge work throughout, the columns in the roadways and ornamental work being of cast iron.

There are to be five stations on the length, not including those already existing at Shortlands and Nunhead.

It is expected that the line, which was commenced in July, 1890, will be ready early in the ensuing year.

The work is being carried out under Mr. John Wolfe Barry, the company's engineer, and Messrs. Lucas & Aird, are the contractors.

At the Crystal Palace District Gas Company's Works, the members were courteously and hospitably received, and accompanied over them by the engineer, Mr. Charles Gandon.

This company was registered in the year 1854, the principal idea then being to supply gas to the Crystal Palace, which had been erected at Upper Norwood, from the materials of the first great exhibition of 1851, in Hyde Park. It was originally proposed to erect gas works at Lower Norwood for this purpose, but a gas works then existed at Lower Sydenham, belonging to the Sydenham Gas Company, and it was finally arranged that the Crystal Palace District Gas Company should lease these works and extend them for the supply of the Crystal Palace and district, and some years afterwards the two companies were amalgamated. The attractions of the Palace and surrounding neighbourhood caused a rapid increase in the population, and consequently in the business of the company; some idea of this increase may be formed by noting that the original subscribed capital of the company was only 24,000*l.*, whereas the present paid-up capital is 381,649*l.*, and that the income for the year ending June last was 148,445*l.* With this rapid increase, the original works and site, which were on the opposite side of the road to the present ones, were soon found insufficient for supplying the ever-growing demands of the district, and new works were established on the present site in the year 1859, the works of the original company having been now long since abandoned. It was not until the year 1858 that the company was incorporated by Act of Parliament.

The present works consist of four retort houses of a united productive capacity of 5½ millions cubic feet of gas per 24 hours, and containing 960 retort mouthpieces, the coal carbonised during the 12 months to June last having been 90,114 tons. In one retort house West's compressed air drawing and charging machinery has been in successful use for the last three years, but, unfortunately, it was not at work at the time of the visit. The condensing, scrubbing, washing, and purifying apparatus, is of the usual character. The company undertakes the manufacture of sulphate of ammonia from the gas liquor, and in connection with this part of the works is an interesting process for the recovery of sulphur from the waste gases produced in the manufactory of the sulphate.

A new gasholder is in course of construction, which will consist of three "lifts," the inner one being 163 feet 6 inches diameter, and each lift being 40 feet 6 inches high, the total capacity of this holder will be 2,500,000. The present gasholders, of which there are five, have a total storage capacity of 3,825,000 cubic feet.

On account of the continually increasing gas consumption it has been found necessary to commence the erection of an entirely distinct works, which will in fact ultimately form a separate section. Of this a building has been erected to be used as an engine boiler and exhauster house, with overhead water tank and underground tar tank; a combined washer scrubber has also been constructed, and a condenser has to be erected, and next year a retort house will probably be added.

5th October, 1891.

W. N. COLAM, PRESIDENT, IN THE CHAIR.

MACHINE STOKERS FOR GAS RETORTS.

BY HENRY O'CONNOR.

THE author does not intend to occupy time this evening with any detailed description of the earlier forms of machines for stoking gas retorts, which have been suggested by different engineers from the time of Murdock. This has been done in a far better style and manner than the author could pretend to, by Mr. John Somerville, in a paper read before this Society in 1873, in which were described all the principal arrangements that had been tried up to that date. Since then, the late Mr. F. W. Hartley read a paper, mainly upon Mr. John West's earlier design of a machine-stoker to work by manual power; this was in the year 1875. From that time, however, to the present, no further record has been made in the 'Transactions' of this Society of the different systems which have been tried, of which some have met with great success, whilst others, heralded at the time with loud trumpetings, have since been allowed to drop into obscurity.

Stoking machinery, in all but the smallest works, is no doubt a means of saving money, and is on that account every day becoming more general in its use. The various rivals to gas, and the necessity of reducing the cost of manufacture to the lowest point, have made gas engineers thoroughly alive to the importance of this labour-saving appliance, and in a very large number of works machine stokers, some worked by power and some by hand, are employed, the result being that the harder part of a stoker's work is done away with, and the time necessary for the instruction of workmen considerably reduced. These last points are of great importance at the present time, as during strikes new men can be brought to the works and quickly given the necessary teaching to enable them to use the machines, and to take the place of those who have left.

Any appliance which reduces manual labour, and at the same time tends to increase the out-turn of gas per ton of coal, recommends itself to the gas engineer, more especially when this can be done at a reduced cost. In a statement made by Mr. John West, of Manchester, at the meeting of the Gas Institute last year, the estimated saving by the use of his machine was shown as varying from 1·34*d.* at Cheltenham to 2*d.* at Maidstone, and 2·7*d.* at Richmond, per 1000 cubic feet; though several engineers who had had the machines in use stated the saving to be about 10*d.* per ton. The difference between these statements is accounted for, the author thinks, by the fact that Mr. West showed the difference between the actual cost with machinery, and the estimated cost at the present time by the old system, while the other gentlemen compared the cost before machinery, eight hour shifts, and increased wages, were introduced, with the cost with machinery and these extras.

The reduction taken at either figure shows an important saving, though the author does not believe these figures represent the total gain by the employment of machinery. That a considerable increase in the quantity of gas produced per ton of coal is obtained is a well known fact, this probably being due to a more even distribution of the coal in the retort and the more rapid method of discharging the coke and recharging the retort with coal, saving the loss of heat, by the lids being closed more quickly, and also, in the case of West's machinery, to the fact that the coal is broken small and is thereby more easily and thoroughly carbonised.

One thing which has prevented the more extended adoption of machinery, is that many retort houses are so restricted for space that a sufficient distance is not available between the mouth-pieces and the back wall. This should certainly be more than 20 feet, though there are cases where machinery is in use where there is not more than 19 feet 6 inches, and at one works only 19 feet. Another detrimental point is the widely differing shapes and sizes of the retorts and mouth-pieces used in the various works; this fact makes it imperative that the machinery should be specially designed for each factory. The shape of the mouth-pieces is a very important item where machine-stokers are to be employed; at the present time ⌓, and oval retorts, are nearly the only shapes used; and in many cases, to ensure a tight joint when the lid is closed, the front of the mouth-piece is made circular; in such a case the opening on the level of the bottom of the retort should be at least the same width as the retort at that point, or on withdrawing the caked coke, it will frequently become jammed into and choke the mouth-piece, thus impeding the work, and causing extra labour. This is the case whether machinery or hand labour is employed; but with the former, the greater power available has been known to draw off, not only the coke, but the mouth-piece with it. This point should therefore be borne in mind by engineers when ordering new mouth-pieces, whether they intend using machinery or not.

Stokers have certainly been quieter this last winter, which is no doubt largely due to the increase in wages, and a general disposition to accede to their reasonable requests. At the same time the determined stand taken by Mr. Livesey and the South Metropolitan Gas Company during the memorable strike of 1890, must have shown that unjust demands will not be granted. The large amount now paid on this account has left its mark on the returns of all gas companies, and should be a strong argument in favour of employing machinery to reduce the quantity of labour required in the retort house.

That most of the machinery now devised for the purpose is too complicated, and therefore more likely to get out of order cannot be denied. This is a serious defect in such a place as a retort house, where so much dust abounds, and that dust of so cutting a nature, as to clog and rapidly wear out the machines. Many engineers are deterred from recommending to their directors the adoption of mechanical stoking, by the fact that the machines are too elaborate. It is quite usual to hear the remark, "I shall adopt machine stoking when the proper system is invented, but no system at present is nearly simple enough to suit me."

Mr. Methven, in his inaugural address to the Southern District Association of Gas Engineers and Managers this year, suggested the use of machinery, principally during the winter months, to obviate the necessity of taking on a large number of fresh hands, and thus to keep the same men on summer and winter. This is a decidedly novel notion, and one, likely, at first sight, to recommend itself to gas managers generally, but the advantages must be compared with the saving effected by keeping the machines in use all the year round, and when the cost for interest and wear and tear has been divided over the whole twelve months. Then again, the author fears that if a large number of men were being kept on and paid to work by hand while the machines were lying idle, whereas only half the number would be required if the mechanical stokers were in use, engineers would consequently be deterred from adopting this method. If machinery is useful, effects a saving, and at the same time obtains more gas of a given quality from a ton of coal during the winter months, it would seem that it should be employed all the year round. It would appear advisable rather to obtain enough machinery to do all the summer work, if not more, so that it may be employed continuously, and the advantages obtained all the year round. This may necessitate the connecting of the different retort houses by lines of rails, so that the machines could be shifted from one house to another, as required. In some works, notably those at Birmingham, machinery is employed only for the purpose of drawing the coke from the retorts after carbonisation. At the works in question, four of these drawing machines, of the pattern invented by Mr. Ross, of America, and introduced into this country by the late Major Dresser, have been in use since 1885. Mr. Charles Hunt, who has expressed his satisfaction with the work done by them, stated at a meeting of the New Institution of Gas Engineers, that the cost of drawing by machinery and charging by hand, in the usual manner, was about 10*d.* per ton. Mr. Hunt's experience of the Ross stoker, was that it was requisite that the coal should be of uniform size, and the cost of breaking and raising it to the hoppers precluded its use in his works.

In a society like ours, which has among its members so many interested in the manufacture of gas, the author does not think it would be considered out of place to describe some of the systems which have been suggested and tried since 1873, and to trace to some extent the reasons of their success or failure. Perhaps the best plan will be to take the different inventions in the order in which they appear in the Patent Office records.

Mr. Foulis was in effect the first to introduce hydraulic power for the purpose of mechanical stoking, and the system has several advantages over the other methods of supplying motive power, in being cooler than steam, and that the waste water after having served its purpose in the cylinders can be utilised for keeping the rake cool, and for sprinkling the hot coke as it is drawn from the retort. A hydraulic pressure of about 120 lbs. to the square inch is used, and the mains are carried overhead, pendulum branch pipes being suspended at every 50 feet and attached to the cylinders by bayonet joints. They allow the machine to travel, and to be worked for a distance of 25 feet each way.

Mr. Somerville's plan of dividing the machines for charging and drawing is followed in this case, and the two operations are separate. In the drawing machine, the cylinder $2\frac{5}{8}$ inch internal diameter is the full length of the travel of the rake, the back end of which forms the piston. The cylinder is mounted on a stand and, swivelled at the centre, which allows it to be moved up to pass over the coke on entering the retort; this is worked automatically by the valve lever. Water can be made to enter either end of the cylinder so as to cause the rake to enter or withdraw from the retort. The charging machine has a cylinder 3 feet long by 6 inches diameter, with chain multiplying gear around it. The end of the chain is passed half round a barrel, to the front end of which the scoop is fixed. This barrel travels forward with two collars one at each end, when the front collar arrives at the end of the machine it stops, and the barrel then runs through it until the scoop is home, when a catch is released and the half turn of the driving chain inverts the scoop and deposits the coal in the retorts; the water is then turned into the opposite end of the cylinder, and the scoop is withdrawn.

Mr. Foulis originally employed ponies to bring the loaded scoops to the machine, but in 1883, that gentleman in conjunction with Mr. Woodward, patented an arrangement by which the coal was brought in long scoops by wire ropes, and automatically tipped into a long hopper fixed above the charging-scoops, no matter at what part of the retort house the machine was, at the moment, in use. An ingenious arrangement was also included in the specification for directing the coal into the charging-scoops at any desired level: Fig. 1 is a sketch of this idea. An improvement in the drawing machinery was also included, by which the cylinder became the moving part or rake rod, the piston remaining fixed to the carriage. The water in this hollow rake rod was continually changing, thus keeping it cool. Mr. Foulis computes the cost of the drawing and charging operations by hydraulic power at from 8*d.* to 9*d.* per ton of coal carbonised. By the kindness of that gentleman the author is able to bring before the Society an illustration of his new hydraulic drawing machine, which is very simple in its mechanical details, and is shown in Fig. 2. On the front end of a light angle iron frame mounted on wheels, an inverted ram is placed, which actuates a chain for the purpose of raising or lowering the rake to suit the varying levels of the retorts. The water under pressure is brought to the top of the framework, and from thence to each end of the rake rod cylinders and to the lifting ram. In this machine the rake rod is no longer the piston rod, as in the first arrangement, or the cylinder as in the second, but is a deep flat iron rod on edge A, travelling along an H iron B, upon each side of which are placed cylinders, one facing forward, C, for inserting the rake, and the other facing backward for withdrawing it. Affixed to the piston rods of the cylinders are pulleys D, with chains working round them, which are fixed to the cylinders at one end, and to the rake rod at the other. The same valve lever admits water to either cylinder according to the direction in which it is moved, and at the same time raises or lowers the end of the rake when it is entering or leaving the retort.

The machine is moved along the retort-house floor by manual power at E, and can be actuated by the man while on its platform.

The author is informed that this machine can be fitted up complete for 200*l.* exclusive of pipes and pumps. Mr. Thomas Fitch Rowland, of Greenpoint, City of Brooklyn, U.S.A., invented and patented in England in 1877, a mechanical stoker, see Fig. 3, of which the salient features are as follows:—A hopper is fixed on the machine, with a rotary valve underneath, the tube of the valve being of a convenient size to hold the quantity of coal necessary for one charge, it thus becomes a measurer of the coal which passes by a telescope shoot to the scoop. The scoop is formed in three pieces. The two sides being joined at intervals by rods with swinging plates free to move in one direction only. At the inside bottom edge are fixed small angle irons, which serve to carry the bottom plate, the latter being corrugated to gain strength, and also to more easily fit over the pipe bearers. The scoop, complete, being filled with coals, is run into the retort by mechanism, and as soon as fully in, the bottom plate is removed automatically by a rack on the underside, the coal being prevented from coming with it by the swinging plates, which remain vertical. As soon as the bottom is quite out of the retort, the sides are withdrawn, the swinging plates being free to hang back to pass over the charge. There is nothing particularly novel about the rake described in this specification, it is worked by friction rollers, and is automatically raised on entering the retort to pass over the coke, and then forced down on the bottom and withdrawn.

In Mr. Hartley's paper, before mentioned, was described West's manual machine, with the pattern scoop he first designed; but in 1878 Mr. West patented a charger, which opened in the middle, as shown in Fig. 4. This scoop he has since fitted to all his machines, at the same time so adapting them that any system of power may be employed, including steam, compressed air, wire ropes, or manual labour. The scoop is made half the length of the retort to be charged, and is therefore run in twice, once to fill up the back end, and then to fill up the front part.

Mr. West has since designed a long scoop, for use with his wire-rope system, which completes the charge in one operation, the entire weight being carried by the machine.

There is no doubt that Mr. West has done very much for mechanical stoking. No man has so continually and so successfully insisted upon its usefulness, and no machines are more generally employed than his. Over 200 of them are now in use at different gasworks in England. In 1886 he patented an arrangement for the adaptation of power driving by steam generated on the machine; the scoop carriage was also made to run on a suspended frame, so that no part of the weight came upon the retort. In 1888 Mr. West adopted and patented a wire-rope system, to work the machine previously described, the wire rope being driven from a stationary engine. This method has been adopted in many places with great success. Fig. 5 shows such an arrangement as suggested for a suburban works. The latest pattern Mr. West has designed is one in which an elevator is fixed upon the machine. This consists of a bucket elevator worked from the main driving gear of the machine, so arranged as to pick up coal from the floor of the retort-house, and deposit it in the hopper above the scoop from which it is filled; in other respects the machine is the same as the 1888 pattern.

Longsdon's patent of 1878, Fig. 6, consists of a scoop or trough, which is brought opposite to and touching the mouthpiece. This is filled with coal, and contains a frame with hinged leaves made to open on withdrawal, but which hang vertical when travelling forward into the retort, and so carry the coal with them. When far enough in, the frame with the leaves is raised and then withdrawn, the leaves hanging back and passing over the coal, which is thus laid evenly on the floor of the retort. It appears to the author that this invention should work well with new retorts, but when they have become uneven with use, the power required to force the frame in would be very great. The rake of the discharging machine in this invention differs from all others in that it has blades at intervals along the rod, see Fig. 7; these blades are again peculiar, as they each consist of five pieces free to turn upon the rod, and open and shut in the same manner as a lady's fan. When the rod is sent into the retort the fans are closed, the rod is then turned, the fan opened, forced into the coke, and then withdrawn. These fan-like heads must be very liable to stick and refuse to open, after being subjected, as they would be in working, to the high heats now used in carbonising.

Warner's first patent was for a machine to raise the coal from the floor by bucket elevators, and by shoots to deposit it in the scoops and for raising in a bucket by a lift, the coke after being drawn from the retorts, carrying it over the framing of the machine, and discharging it through openings in the wall of the retort house. This was necessitated by the peculiar position of the house, which was blocked at both ends, so that all the coal and coke had to enter by openings in the back wall. This patent was taken out in 1875, and in 1878 Mr. Warner took out another for a simplification of this. The scoops he then proposed to use were of the ordinary pattern, but were actuated by mechanism driven by a square shaft working in bracket bearings. The arrangement of the floor of the retort house required for this apparatus is peculiar, and would preclude its ready adaptation in many works. The author believes it is still working at South Shields, where Mr. Warner is the engineer.

The stoker previously mentioned, as invented by Mr. Ross, of Cincinnati, was patented December 30th 1878, and consists of an arrangement for forcing the charges of coals into the retorts by compressed air, steam, or gases, see Fig. 8. The hopper A being filled with coal, the charger is run forward until the mouth B enters the retort. Steam is then turned on to the jet C at the back end, and the coal is forced into the retort, the coal above falling into the conduit as rapidly as the contents of the latter are blown into the retort.

In 1879 further improvements were made in this machine, the boiler was made part of it, and means were provided for raising or lowering the charger to suit the height of retorts by the same power as used in charging. In this form it was adopted at Nine Elms, and tried at Marseilles for patent purposes, and at Birmingham. The author is informed that the coal did not on all occasions reach the back of the retorts. At that time a steam pressure of 80 lbs. was used, it is now proposed to employ 120 lbs. at which pressure it is working most successfully in America, and to bring it into operation again at the Nine Elms Works. The simplicity of this apparatus is its principal feature, there being so few working parts to wear out. The rake is a rod having upon its upper side a rack, into which a toothed wheel gears. This wheel being actuated by power, moves the rake in or out of the retort; the head of the rake is elliptical, with saw teeth on the lower edge, hinged so as to pass over the coke on being inserted. Four of these machines were fitted up at Birmingham before 1885, and the author understands are still in use there and working satisfactorily.

Mr. Longsdon, about the middle of 1879, brought out an improved rake, the back end of which was fixed to a carriage which ran on a rail set in the direction of the longitudinal axis of the retorts. This carriage took the entire weight of the rake until it was quite in the retort, when a lever was automatically released, and half the weight of the rod came upon the coke and the head, hinged to the end, was forced into a vertical position. The carriage was then run back, bringing with it the rake and the coke from the retort. This is a somewhat elaborate arrangement, and would require harder work than the ordinary rake. It is hardly a step in the right direction.

In 1883 Mr. Grice obtained provisional protection for an arrangement by which the scoops were fixed on an endless band which was run into the retort. The scoops being rapidly withdrawn, caused the coal by its *vis inertia* to remain in the retort. This arrangement was improved upon in Mr. Grice's patent of 1884, see Fig. 9. A long horizontal shoot or trough, of a somewhat less width than the retort, and capable of being made to enter it, is fixed upon the machine, and around this shoot, on rollers at each end, is placed an endless band or chain, with scrapers or vanes fixed upon it at short intervals. The trough is run in, and the scrapers when started pass along on the underside, serving to withdraw the coke. The retort cleared, coals are dropped into the shoot from above, and are carried in by the scrapers and deposited in the retort. The coal for the mouth-piece end has to be carried to the back, and scraped along the retort. No doubt this apparatus could be made to work, but the retorts would have to be of a very deep section to permit the scrapers passing in over the coke.

A decidedly novel idea was that of Mr. T. Jefferies, patented in 1885. He arranges three shoots for simultaneously charging three retorts. These shoots are pivoted in the centre so that they can be inclined at an angle of about 45°, the lower ends are then closed, and the shoots about half filled with coal. They are next brought to a horizontal position, and opposite the retorts to be charged; the rear ends are now closed, and the front opened. Into the rear end a mixture of gas and air is passed and ignited when an explosion takes place, and the coal is shot out into the retorts in an even layer. The author has not been able to learn that this device is in use at any works.

The next upon the list is that of Mr. J. Atterton, see Fig. 10. This is a manual-power machine, designed principally for use in small works, and which appears to answer the purpose well. The scoop is laid upon a sort of trolley and having been filled with coal, if necessary at the store, is wheeled to the front of the retort, and raised from the trolley by self-sustaining pulley blocks, the scoop being carried in a cradle. When the lid of the mouth-piece has been struck and the coke withdrawn, a roller is hung on the front end of the mouth-piece. This roller fits the bottom of the scoop, which having been previously raised is now in position to rest upon the roller, when the stoker takes hold of the handle and drives the scoop to the end of the retort and turns it over. On withdrawing the scoop it is raised, the edges resting upon the high sides of the roller. Thus, the charge when once deposited is not disturbed; the operation can be completed and the lid closed, the author, is informed, in less than two minutes. The scoop is rolled perfectly cylindrical, that is to say, is in section a true half circle, and is made of steel in one piece, so that one stoker can drive and turn it with comparative ease. The apparatus is in use at Haverhill, Southborough, Netley Hospital, Swinton Works, and also abroad, and can be supplied for about 10*l*. It seems to the author that if by the addition of a roller to an ordinary mouth-piece, one stoker can drive and turn a scoop containing 3 cwts. of coal, this part of the apparatus might with advantage be introduced into all works where ordinary hand-scoop charging is carried on, as it must decidedly lessen the labour. Again, the shape of the scoop should assist in the turning over.

Mr. Leutz, of Vienna, patented in 1887 an invention which the author is informed is working very satisfactorily in that city. This invention is shown at Fig. 11. It consists of a long bend (A) with a funnel (B) at the upper end to facilitate the insertion of coal, and by the force of gravity it passes down the bend and deposits itself with perfect evenness throughout a ten-foot retort. Some time back the same idea occurred to the author and not then being aware that Mr. Leutz had already patented it, he carried out, by the kindness of Mr. Carpenter, some experiments, and he is bound to say that he found that the friction on the sides of the pipe was so great as to stop all the impetus due to the force of gravity.

Mr. McDougall's patent No. 3495 of 1888 is for a continuous system of carbonising, which bears a striking resemblance to Brunton's invention of exactly 50 years before. Coal is raised in front by an endless screw in a tube, and is forced into the retorts by plungers which are supposed to drive the coke out at the other end, whence it falls into a water trough sealing the down pipe from the back end. If a system of continuous carbonisation is required, coal may be introduced in small quantities, having been first broken very small, and allowed to trickle down an inclined retort set at say 45° with the horizontal, and of such a length that during its passage from the top to the bottom the small quantity of powdered coal would be practically carbonised, when it would fall into a chamber where it would be joined with that previously fallen, and could be thence withdrawn from time to time.

Mr. James Cunningham, in 1888, designed a hand-charging apparatus, see Fig. 12, in which substantially the ordinary scoop is used, the only difference being that a small roller is placed at the front end. An overhead pair of gantries is arranged to traverse the retort house, from which hang, at the retort end, a loop which is a fixture, fitting the bottom of the scoop, and at the other or handle end of the scoop another loop which is dependent from a trolley or carriage; this is free to travel along the gantries, and so take the weight off the stokers hands. Means are provided for raising or lowering the scoop to suit the height of the retort to be charged, which are not shown on the diagram.

Another arrangement bearing a striking resemblance to an earlier form of scoop is that patented in 1889 by Mr. Runge, in which, like Mr. Rowlands, the bottom is withdrawn before the sides, which latter are curved, presumably to suit circular retorts.

In 1889 Mr. Somerville again entered the field, and in conjunction with Mr. Cutler patented an apparatus for hand power. The charging apparatus is made of a quadrilateral frame on wheels, on one side of which three or more scoops are placed to suit the level of the retorts to be charged. These scoops are driven by means of handles working pinions and spur wheels which again actuate chain pulleys and endless chains fixed to the rear end of the scoop, by which it is drawn into or out of the retort. The scoop runs on rollers, that nearest the mouth-pieces being adjustable. The scoop, which is of a peculiar construction, shown on Fig. 13, having been filled with coal, the machine is brought in front of the retort to be charged. The roller nearest the retorts is then adjusted to bring the scoop to the proper height to enter, and upon turning the winch handle the pulleys revolve and cause the chain to draw the scoop into the retort. When the scoop has reached its extremity, the scoop handle is actuated by the attendant, when the sides of the scoop diverge, and the coal falls on the bottom of the retort; upon reversing the motion of the winch handle, the scoop will be drawn out into its original position and the mouth piece may be closed. The rake, which has a hinged head, is mounted and worked by chain gear in a very similar manner.

Mr. Roscoe, of Hyde, favours the principle of removing the bottom of the scoop before the sides, and in his patent of 1889 he has arranged a most ingenious system of gearing, so that when the scoop complete has been run in and the coals deposited by the bottom being withdrawn, the sides are made to travel twice as fast as the bottom plate, and the whole comes to rest together ready to receive the next lot of coal from a hopper with a measuring valve placed above. A modification of the gearing has been designed for the purpose of withdrawing the division plate in Mr. Trewby's system of charging inclined retorts, which will be mentioned later on.

Mr. C. Eitle, of Stuttgart, Germany, patented on November 7th, 1890, an apparatus for facilitating the charging of gas retorts of which Fig. 14 is a representation. A hopper is provided to hold the charge of coal, and by the action of the revolving open spiral or worm C delivers it in proper quantity to the casing and revolving wings. By this arrangement the weight of the material is not upon the spiral which delivers the coal intermittently, allowing the wings B time to arrive behind the delivered coal and send it forward without any clogging or stopping up. Upon turning the wheel D the wing drum and spiral are caused to rotate by means of spur wheels G and F. This apparatus is carried upon a very light frame, which travels in front of the retorts, and has upon it means for raising and lowering the charger to suit the different heights of retorts. It is stated that the bed of coal in the retort will not exceed the height of the opening at the outlet of the casing, and will be spread evenly from back to front. If it were not for the ingenious arrangement, by which only a small quantity of coal enters the paddle box, as it may be styled, the power required to work this machine would be so great as to put it quite out of the question.

Mr. Freeman of the Wandsworth Gas Works has a manual machine, see Fig. 15, which is exceedingly simple, and which does away with a great deal of the hard labour of the stokers.

It has also another advantage in that it can be fitted up in any retort house where there is sufficient space to work the ordinary hand scoop. It consists of an upright frame of angle iron with wheels at top and bottom, running on rails, one fixed on the floor and another on brackets, on the back wall, or on the columns which divide the retort-house from the coal store. Upon this frame is a horizontal swinging jib, with a roller at the front end, fitted so that it can be moved up or down, by differential self-sustaining pulleys and chains at each end, to any height to suit the retorts. Upon this jib the scoops are laid; they are of the usual pattern, and are placed side by side, fixed at the back end to a small carriage with rollers above and below the jib. The usual tie cross bars at the back end are done away with, and are replaced by a bent handle on each scoop, and which serve to turn them outwards from each other when in the retort.

The action of the apparatus is as follows:—The scoops are filled, in a position at right angles to the direction of the retorts, from a platform which runs the whole length of the house, and is always full of coals. The jib is then swung round and a stoker on each side pushes the scoops in by means of handles on the back carriage; they then turn them over and withdraw them, the coals by this means being spread in a thin layer against the sides and bottom of the retort. While one stoker is backing up the coals and fixing the lid on the mouthpiece, the other is swinging back the jib and getting it into position for refilling and charging the next retort. An arrangement is now being designed for adapting steam to work this machine.

The latest additions to the list are Mr. Woodhouse's charger and rake: both of these contain some novel features. The scoop is made in two halves longitudinally, as shown in Fig 16, capable of being joined together on the underside by long pin and eye pieces. Three sets of rollers are provided to assist in sliding into the retort, and a rack and pinion gearing at each end of the scoop serves to open and shut it. Means are also suggested for raising the scoop by the use of a swinging jib.

The rake, Fig. 17, has two prongs hinged about three parts of the way in, and one scraper at the extreme end also hinged to pass over the coke on entering. A link rod on the underside engages with a toothed wheel in front of the retort, and by means of a handle serves to move the rake in or out. Two steadying or guide-rollers are provided for supporting the drag-rod.

The latest idea of a drawing machine is to insert a scoop, made of steel of the same section as, but slightly smaller than, the retort, with the front edge sharpened, under the caked coke, and remove the whole bodily. It is claimed that by this means the retorts last much longer, and the coke is obtained in larger pieces; the invention is patented by Messrs. Keetman and Bach of Germany.

The author does not think it would be right in this paper to omit a notice of the various machines invented for charging sloping retorts. The question of the superiority of sloping of horizontal retorts, is not for him to consider, so he will content himself with recording the different systems adopted for placing the coal evenly in the retorts.

When Mr. Coze first arranged his settings he had the upper ends of the retorts continued up through the beds by means of cast-iron bends ending in horizontal mouth-pieces and lids. When it is desired to charge, the lids are opened and a truck containing three scoops, shown in Fig. 18, is brought opposite the mouth-piece, and the scoop tilted so as to cause the coal to slide down into the bent-up pipe, and finally form a layer in the retort. These scoops are furnished with swinging plates at the ends, so as to prevent the coal being shot out beyond the mouth-piece, the action of tilting these plates being done automatically. This truck weighs about 16½ cwt. when empty, and holds about 9½ cwt. of coal.

An arrangement was tried at the Kensal Green Works to adopt a lever, on the same principle as the patent railway-waggon shunter, to enable one man to move the charging truck; but owing to insufficient space a very slow speed only was obtainable. A system of handles at each end and bevel wheels gearing on to the axles of the trucks was found to accomplish the required speed, and was therefore adopted.

Then came Messrs. Morris and Van Vestrant's modification of Mr. Coze's setting, by which vertical doors are used at both ends of the retorts, and the trucks, which are made to suit the method of coal supply whether from barge, coal-store, or truck, are then hoisted above the level of the hydraulic main, which in this arrangement is at the upper end, and run on rails, fixed parallel to the front of the beds into position over the shoot. The coals may also be raised by a bucket hoist into a hopper at the end of the house, and from thence the truck may be charged. The truck is divided by partitions into two or three charges as convenient, each compartment having separate slides beneath each charge to permit of the coal being used from any one desired. The coal from these trucks passes through a light, movable telescopic, adjustable shoot, see Fig. 19, which also travels on rails overhead, and which has a bend at its lower end to insert in the mouth-piece. This shoot can be varied to suit every class of coal from slack to broken cannel.

Mr. Van Vestrant in 1890 patented an improved charger, which is shown by Fig. 20. A hopper is carried on a rectangular frame on wheels, and is filled with sufficient coal to charge one retort. It is wheeled to the front after being adjusted by the chains which hold the bottom A, hinged at B, and the flap C, to suit the height of the retort, and to allow the requisite velocity of the issuing coal to obtain an even distribution over the floor of the retort, by increasing or diminishing the angle of the bottom of the hopper. The bottom A is then lowered, and the front delivery flap C opened, the issuing material being thus allowed to gravitate into the retort. The dotted lines on the diagram show the position of the bottom flap when closed.

On the 30th November, 1889, Mr. G. C. Trewby, the chief engineer of the Gas Light and Coke Company, patented an invention for charging sloping retorts, the principal object of which is to spread the coal evenly in the retorts by means of a movable steel division-plate, which is inserted in the retort prior to charging. A hopper may be combined with this plate to guide the coal into the space between the plate and the floor of the retort; when the charging is done, the hopper and plate are removed, and the lid of the retort fastened down. This method permits of the retorts being set at a greater angle, i. e. 38°, than that originally suggested by Mr. Coze, thus securing the more easy discharge of the coke, which, if properly burnt off, falls immediately when the lower door with its stop, the invention of Mr. Wren of Beckton, is opened.

For delivering the coal to the retorts, an arrangement patented by Mr. Ruscoe, of Hyde, has been used, by which the coal first enters a measuring chamber to ensure the proper quantity being used, and then passes under the division-plate and charges the retort. The division-plate is then withdrawn by machinery, while at the same time a fresh quantity of coal enters the measuring chamber so that no time is wasted, and all is in readiness to charge the next retort.

Mr. Braidwood of Greenwich, has arranged a modification of Mr. Coze's system. He sets the retorts at an angle of 36° instead of 29½°, and thus obtains in the same way as Mr. Trewby an easy discharge of the burnt-off coke. To secure an even layer of coal in the retort at this angle, he has patented an arrangement whereby the coal is delivered with the force found necessary for the particular inclination and the description of coal used. A truck, running on rails on the top of the settings, containing two tilting boxes mounted on trunnions, with the centre of gravity well forward, each made to carry a charge of 6 cwts., is brought over the back mouth-pieces, so that when the lever is pulled which opens the door, and releases the catch, the tilting box commences to tilt, and allows the coal to enter the retort. It is prevented from doing so too suddenly by being connected to the piston of an air-cylinder, fixed at the back, causing a retarded delivery of the coals, and thus obtaining an even layer in the retort.

Mr. Braidwood has also recently protected in connection with this truck a travelling shoot, the interior of which is so constructed that the coal is allowed to enter the retort at the exact speed required.

Mr. Hunt's charger, shown by Fig. 21, consists of a horizontal iron framework or platform, mounted upon wheels, capable of being moved longitudinally in front of the benches. Upon this is another framework, also upon wheels, so that it may be moved forward or backward from the retorts. A hopper is suspended by chains working over pulleys, to enable it to be lifted to any desired height on turning the handle at A. A door at B and a shoot C are provided to the hopper, which is filled with coals from a fixed shoot.

Mr. Henry Woodall, formerly of Leeds, brought out a charger, shown by Fig. 22. The lever or handle H is for the purpose of raising or lowering the shoot to the required height, and at the same time of inserting the lower end of the bend into the mouth-piece, a catch is provided for fixing this lever by means of the quadrant Q. Separate shoots are required by this system for each row of retorts. Mr. Lampard has brought out an arrangement for carrying three or more shoots of different lengths to suit the various levels of the retorts. The shoots are fixed on a turntable, and the turntable upon a truck, capable of being run from end to end of the retort house, and brought opposite the mouth-piece it is desired to charge.

The author thinks this concludes the list of the machines, which have some slight chance of solving the problem of how to reduce the labour required in the first operation of manufacturing that most necessary article, coal gas. There is no doubt a tendency, at this end of the century, to improve the minds of the labouring classes, and this spread of education is causing a scarcity of workmen who are content to be mere "hewers of wood and drawers of water." As the mind improves the objection to purely manual labour increases, and more men are desirous of undertaking, and more capable of understanding, the somewhat elaborate machinery which is being designed for carrying out the processes of manufacture necessary for our every-day requirements.

In conclusion, if the author has been able, by means of this paper, to introduce to any engineers entrusted with the care of works for the manufacture of gas, any system which they may consider suitable to the requirements of the locality in which they may be interested, he will be fully satisfied that any time spent in the preparation of this paper has been well spent. And he hopes that in the course of the discussion, the cost of working of the two systems of inclined and horizontal retorts may be fully dealt with.

DISCUSSION.

In proposing a vote of thanks to Mr. O'Connor for his paper,

The President said that within the last week they had an opportunity of going through gas works, and seeing some of the machines employed for retort charging; they did not have the opportunity of seeing them at work, but they understood that they worked satisfactorily. The matter of using machines resolved itself into a question as to whether it paid, taking everything into consideration. The attention of engineers just now must be to a great extent concentrated on the endeavour to produce labour-saving machines and machines for dispensing almost entirely with labour. They all knew what trials they had lately been going through, and how machinery had come to their assistance. He therefore felt that this was a very opportune occasion for the paper to be brought before the Society, among the members of which, he was glad to say, they had many who took a deep interest in, and who were more or less connected with, gas production; and he therefore hoped that they would have a very interesting and instructive discussion on the paper. From his own observations he thought that the engineers who had been engaged in producing the various machines must have had a great many difficulties to contend with. Heat, he should presume, had been the most difficult element to contend with. The tendency at first seemed to have been to make the machines a little too delicate, and now their endeavours were directed to making them more simple. He was not at all surprised that some managers of works, in reply to Mr. O'Connor and other gentlemen, stated that they would like something very much simpler than they had seen before. With regard to charging retorts by gravity, he should be inclined to think that the success of such a mode would depend very much upon the homogeneity of the coal. If the coal varied very much, he should presume that the result of the shoot would vary also. They must all agree that the paper, as produced by Mr. O'Connor, was well handled, and that it had been fully illustrated by diagrams and very interesting models.

Mr. Perry F. Nursey said that about a year and a half ago he examined into the working of the Morris and Van Vestrant system of inclined retorts, to which the author had referred, and was able to report favourably upon it. He had brought to the meeting a diagram, Fig. 23, showing a cross-section of a retort-house on this system, with the settings back to back as put up at Barnsley. The diagram also showed a front view of the charging arrangements. The upper end of each retort, which is of D pattern, is fitted with the ordinary mouthpiece, and a movable charging-shoot runs on light rails in front of the setting. The charge of coal is run from the truck above down the shoot, at the lower end of which is a hinged adjustable shoe, by which the velocity of the falling coal is controlled. He had first tested the system with a single retort at the Brentford Gas Works at Southall, and afterwards witnessed the working of a full setting of 20-feet retorts. Fig. 24 shows a single house with 15-feet D retorts, six in a bed. Another example of the gravitation system was seen at Fig. 25, which showed the settings with the charging side near the wall and the coke-hole between the settings, as put up at Coventry. One view shows the ascension-pipes at the top, and the other with them at the bottom. To show that the advantages of the Morris and Van Vestrand system were recognised by practical men, he might mention that the system had been adopted by seven of the metropolitan gas companies, by eleven of the provincial companies, and by one company in the Colonies, while twelve other companies were arranging for its adoption.

Mr. Charles Gandon said that he had only had experience with one system, and of that he could speak very much in favour, although he had great hopes that its inventor might be able to improve on it still more. He referred to the West system of drawing and charging retorts. He remembered seeing, many years ago, the first plan that Mr. West brought out, which was what one might call the "manual" charger. It did not depend upon motive-power for working. He was then very much struck with the simplicity of it. The author of the paper had laid stress upon the point that it was essential to have the most simple machinery possible in the retort-house, because of the liability of it in such a place to get out of order. He thought that Mr. West's manual stoker was one of the most simple he had seen, and he believed that it worked successfully wherever it had been applied; but he could not say he had had any personal experience of it. As the author had pointed out, Mr. Foulis was, perhaps, the first to introduce machine stoking into the retort houses. He did not think that the hydraulic stoker had been very largely applied. He remembered seeing it at Manchester, and it had, perhaps, the drawback that there was too much machinery about it. Since then he believed Mr. Foulis had considerably simplified his machine, and he had been given to understand that it was working very satisfactorily at Manchester and Glasgow. Mr.

West had, he thought, certainly been the most successful of any who had introduced mechanical stoking. The great point with a machine was, would it induce economy? Would it enable gas-managers to do with less labour, or with less skilled labour? He was of opinion that it required even more skilled labour than the ordinary hand-stoking; but could they do with less labourers? His answer was, "Yes." He had had Mr. West's compressed-air machine at work at the Crystal Palace District Gas Works for the last three years. At the commencement it worked unsatisfactorily; the second year it worked better; and last winter they had very little to complain of. He could not say that he had been able to effect the economy which others professed to do with the same machinery, but still there had been a small economy. Probably they would realize more presently. At present they were obliged to draw the coke out upon the floor of the retort-house, and that considerably impeded the action of the machines. They were now trying to get the coke out of the way so as to allow machines to work more freely. He believed that since they had put their machinery down Mr. West had introduced some further alterations in the way of working by means of wire or cotton ropes. That seemed to him, Mr. Gandon, to be an improvement, but he had not had any experience of it. Mr. O'Connor had advocated the putting up of sufficient machinery for working throughout the year. He, the speaker, could scarcely agree with him there, because all machinery required repair; and he thought that it was a very good plan to have sufficient machinery to do the work during the winter, and to stop it in the summer in order to repair it for the following winter. The more complicated the machinery the more liable it was to break down, and, as might be expected, it always broke down in the middle of the night, or just when it was most awkward. Therefore, he thought that it was well to have some hand-working retorts that they could fall back upon. Reference had been made to Ross's machinery. He had seen that at work, and he must confess that he did not like it, because there were some very ponderous parts to actuate, and a very high pressure of steam was required to insure anything like satisfactory working. Mr. Braidwood's invention for tilting the coals into the retort had been described to them. It seemed to him to be a very good arrangement, but was it not a disadvantage that the gas had to be drawn from the bottom part of the retort instead of from the top? It seemed to him that it would be difficult to make the gas travel downwards. He had had no experience of inclined retorts, but it occurred to him that any angle which they might adopt, when the retorts were perfectly new and smooth in the interior, would not be applicable when those retorts got deposits of carbon on them. Whether the tilting machinery, by which they could get a different velocity for the coal entering the retorts, would overcome that he was not prepared to say. A good system of inclined retorts ought to very materially decrease the cost of charging and discharging. The most satisfactory plan, perhaps, was that of Mr. Trewby, which was to put a plate in, and allow the coal to run in between the plate and the bottom of the retort; the steeper incline also favoured the discharge of the coke. He was simply expressing that as an opinion; whether it was so or not he must leave others to decide.

Mr. W. A. VALON said that he thought that some system of charging and discharging retorts, not entirely dependent upon hand labour, should be used by every manager throughout the kingdom. Some twelve years ago he introduced into his works at Ramsgate, and one or two other works, a simple arrangement which Mr. West called his manual-machine. That machine had been at work for twelve years, and he, Mr. Valon, could only give his testimony to the fact that it worked very well. They had had nothing to complain of, and they had relied upon it entirely for the carbonisation of the whole of their coals during that period. Perhaps for one or two days out of the twelvemonth they had had to stand still for the purpose of repairing the machine. A cogwheel would strip, or something of that kind, but they had had no serious breakdown of any kind. As to the saving effected by the machine there was no doubt whatever. At Mr. West's request he asked their accountant to take out the saving per ton of coals by the machine, during the last ten years, and it averaged from 1*s.* 1*d.* to 1*s.* 3*d.* per ton. The wages at Ramsgate were not, perhaps, quite so high as they would be in London, and that ought equally to show a larger amount in favour of the machine. He had seen Mr. West's arrangement with wire rope and compressed air. They were very beautiful arrangements, and they did him very great credit so far as mechanical skill was concerned; but he, Mr. Valon, must say that in order to introduce either Mr. West's wire-rope machinery or any other, the most of which was of very little use, he should not think of doing away with the simple manual machine. With regard to sloping retorts he did not quite agree with what Mr. Gandon had said. He had seen the sloping retort in all stages of development, and had made experiments with it 20 years ago in Sheerness, in conjunction with Mr. Carpenter. It was a failure, for reasons which he did not think had been surmounted. One speaker said that the success or non-success of the system depended a very great deal upon the character of the coal with which they had to do, and that undoubtedly was a fact. With dry coal, cannel coal and other of similar nature, the sloping retort might be a comparative success. With soft, caking coal he had yet to find that it had been a success. The slightest impediment in the retort was a very great nuisance, and led to a great deal of trouble. He had not yet found any section of retort that would take so much coal perpendicularly, or in a sloping position, as it would horizontally; nor did he think that retorts with the aid of a simple manual-machine were so well worked in a sloping position as they were in a horizontal position. He did not believe that they were more cheaply worked. Sloping retorts looked very well on paper, and he was very much fascinated with the idea when he first saw it, and spent considerable time and money in endeavouring to make it a success. He did not think that it was a step in advance so far as the carbonisation of coal was concerned. First of all it took up a great deal more room, and he could assure the meeting that though the man in the picture looked very cool, he was really terribly hot. A man working on the top of the beds must be very much worse off that a man working at the side, and comparatively at their bottom. Sloping retorts were introduced for the purpose of doing away with machinery, but it seemed to him that they were only the commencement of the introduction of machinery. Mr. Nursey had said that they had been applied to fourteen works. He, the speaker, should like that to be qualified a little, if Mr. Nursey would do so. He might say that they had been applied experimentally, but to say that they would be retained by those fourteen works was rather premature. He, Mr. Valon, had seen works where they would be very glad to get rid of them.

Mr. NURSEY said that he was much obliged to Mr. Valon for his observations. Whether the retorts had been permanently applied or not, he could not say. He simply took upon himself to give to the society information which he had received, and he was unable to qualify from personal knowledge what he had said. With regard to the cost of charging and discharging, he witnessed a working test of the system at Southall. It was made comparative with a bench of seven 20-feet through-retorts on the horizontal system, which was first drawn and charged by ordinary trained stokers. There were three men at each end of the setting, and the time occupied in drawing the coke was 4¼ minutes per retort. The time occupied in charging each retort with 6 cwt. of coal was

50 seconds. In the case of the retorts on the gravitation principle, there was also a setting of seven through-retorts of the same length and section as in the previous case. The work, however, was not performed by trained stokers but by yardmen. With one man at each end of the setting the drawing of the coke from each retort was effected in 1¼ minutes, and the charging of each with six cwt. of coal was accomplished in 15 seconds, notwithstanding one or two slight hitches due to want of training on the part of the two men.

Mr. Valon said that the time occupied in the discharging of the retorts was very excessive. It should only have been a minute and a half, instead of four minutes and a half.

Mr. Van Vestrant said that he was sorry that the reader of the very interesting paper on retort charging had failed to mention a very successful method of working inclined retorts, and which had been seen at work by many of the members in the meeting who could verify his statements as to the ease, simplicity, and effective method of charging and discharging the retort by gravitation, notwithstanding the statement of some, that sloping retorts were not successful; the one to which he alluded was the inverted Y plan of Mr. Alfred Kitt, of Pimlico, the coal being fed into the central leg of the Y retort, in the middle of the setting, and thence falling in even distribution on each sloping retort, whence it fell out after carbonisation, on opening the mouthpiece. A great deal of the success in working the sloping retorts consisted in thoroughly burning off the charge of coal. If the heat was insufficient to thoroughly coke the coal then there arose nearly as much difficulty in drawing the charge as in ordinary horizontal retorts. The difference in time in drawing the retorts already mentioned in the discussion is caused, simply, by the better heats obtained in one works over another; at the present moment at some places where the sloping retorts were at work, complaint is made that the coke rushes out of the retort, on opening the lower lid too quickly to be convenient. He had seen the charges, immediately the handle was unfastened, push the door open and immediately fall on the retort-house floor at such a speed as to necessitate great care on the drawer's part, otherwise there would be danger of burning. He knew of one or two works where the heats had been defective from bad furnace working, from the very beginning, and in one case the sloping retorts had been thus improperly worked from the commencement, and were classed as failures. To draw the charge of coke as easily as claimed from the sloping retort, the question of good heating becomes a necessity, but the advantage of this system lies principally in getting rid of any scoop or carrier that goes into the hot retort. With ordinary scoop work the greatest difficulty in working is caused by the retorts varying in size and shape through the scurfing and warping of the retort, and when the charge of coal is in, the scoop jams, and gets fixed against these inequalities. This occurs both in hand and machine charging; in the former case, human adaptability is brought to bear in getting the scoop back, necessitating occasionally the three men all pulling at once; in the case of the machine, where a reserve of power is employed, damage to the retort or mouthpiece is apt to occur, and to meet this, increased depth of retort is resorted to, so as to avoid this evil. This, however, necessitates an alteration in the ironwork of the settings, and it is evident, therefore, that if it be possible to do away with this coal carrier going into a red-hot retort, a great advantage is gained, and that where the coal runs into the retort by its own weight, these difficulties are obviated. With machines containing frictional parts, and exposed to the tremendous heat of the setting, the difficulty of proper lubrication is insurmountable, giving rise to the break downs already pointed out. Mr. West had overcome many of the troubles of machine-stoking in a very skilful manner, much was due to his previous experience of the requirements in carbonising coal, but his plan was still expensive, costing as much as the setting itself when structural alterations were taken into consideration, but it enabled engineers to dispense with, or be independent of, the stoker, to a certain degree, and the possibility of doing away with skilled labour gave the engineer in charge great advantage with regard to the choice of men; but to replace the stoker by a skilled engine driver is still to be avoided, if it can be met by placing retorts so that the coal can be run into them by opening a valve or flap. Messrs. Clegg, Wilson, Aitkins, and others, had tried to get a retort charged by falling coal, but had failed on account of the difficulty of getting an even layer on the floor of the retort. Mr. Carpenter's plan worked very well, but had machinery for feeding, and failed from the fact of the delivery of the hot coke into the chamber being at the back, so that the carbonic oxide caught fire and damaged the setting. If it be possible to evenly charge a retort by tumbling the coal in, then all machinery and carriers going into the retort can be done away with, indeed, engineers should have found this out many years ago. Coze had shown them how it could be done, and now it was merely a question of what system of charging should be adopted. With the sloping retort any class of coal-dust, small, mixed, or large, could be evenly charged, and even large lumps as big as a man's head had been put in with small coal with the result, contrary to expectation, that they did not jump over the finer layer of coal but simply stopped when the stream of incoming coal ceased, and remained in their place in the retort projecting above the small coal. If the heating of the setting were not attended to, difficulties in drawing arose, from caking coal and pitch; these difficulties, not being due, however, to the sloping of the retort, as there was no difference in the setting over ordinary sets, except that one end of the retort was raised to the requisite angle to allow the coal to flow. As to the question of raising the coal to the required height, it had to be brought into the retort house in any case, and while being wheeled there it was a simple matter to raise it to a sufficient height to give the requisite fall for gravitating into the retort. The original form of cast-iron shoot had, in cases of defective heating, caused defective delivery. The heating of retorts is in all cases rather a ticklish thing, as in a given time the whole of the gas is required to be driven out of the charge; any excess of heat tending to soften the shoots when built into the benches, and too low a heat preventing the charge from being burnt off. But where well managed they were very successful, as at the Southall Works of the Brentford Gas Company, where they were at work to this day. The objection to this form was the expense, as they cost double the price of ordinary retorts, but with the simplified English form, as on Fig. 23, of a through retort, the cost was the same as ordinary settings. With regard to properly charging the coal, if the retort was placed at the angle approximating to that of the angle of coal repose, and the coal run into the top end, when it came to the stop placed at the bottom, the coal would stop the whole length of retort, and Mr. Hunt, of Birmingham, was using retorts 23 feet long, no matter what the quality of the coal, lumpy, fine, or slack. As to the question of economy in working, it was entirely a question of the rate of wages paid. In one case he knew of two men having worked 42 retorts for 12 hours for 4*s.* 6*d.* each per day, with charges of 5 cwt. per retort, the cost being about 5*d.* per ton for stage labour. In London the wages rate is higher; the saving in cost of labour on the ordinary plan was from 60 to 70 per cent. less than ordinary stoking, and freedom from special class of labour. As regards his own personal opinion, when he first saw the settings at work at Mr. A. Coze's works, at Rheims, and the easy manner in which the coal was delivered into the retort, viz. by merely tumbling the charge into the upper end, and the even layer which it formed in the retort, he then felt that the sloping system must eventually supersede all others, and that it was merely a question of time.

Mr. J. Tysoe said that one remark had been made which he should particularly like to be clear about. The author stated that the cost per ton for drawing by machinery and charging by hand would be 10*d.*, and that drawing by machinery and charging by machinery came to 8*d.* or 9*d.* Taking the lower figure that would allow 2*d.* for the saving by the charging machinery. It seemed to him that the charging machinery must result in a much larger saving than that. His experience in machinery had been gathered from Mr. West's latest improvements, worked by the wire-rope system. It was being operated now in the works under his charge at East Greenwich, and had been working for about seven months, the consequent economy being certainly very great. It worked on a section of 150 retorts, and he had proved the saving by actual results to be equal to 11*d.* per ton. That was a very considerable amount, and he thought that it was worth anyone's while to introduce the machinery if the saving could be depended on, as his experience showed it could be. In the place of 30 men they had 14 men only. At the first introduction of the machinery they had the boilers and engines on the machines themselves. These gave them a very large amount of trouble, as breakdowns occurred in the middle of the night, but since the alteration to the wire-rope system things had gone on very smoothly. The cost for wear and tear was very little in excess of the cost of that arising from ordinary hand charging.

Mr. W. J. Warner said that his machinery was introduced into the South Shields Gas Works somewhere about 14 years ago. It had been driven from the first by an endless rope, and had continued to work day and night ever since. They had had no breakdowns but those which could be remedied at once, and without practically stopping the machine, in fact, they literally knew nothing about breakdowns. He was quite surprised to hear of some four or five minutes being given as the time for drawing and charging retorts. This was a new experience to him. At South Shields they had 15 beds, eight in a bed, going on regularly, with about a minute each for drawing and charging. With reference to the cost of doing the work by machinery he did not think that it had been put forward in a plain business-like way where the subject had on previous occasions been discussed. In making comparisons he thought full particulars should be given of the average ordinary working of the district into which the machinery had been introduced, the average cost per 1000, or per ton of coal, and the produce and profit per ton, the dividends, the selling price of gas, the original cost of the machinery and the interest on it. Those who had had charge of machinery had done neither themselves nor their subject justice in dealing with this somewhat complex question. Every detail should enter into these estimates, so that gas managers might have the facts clearly before them in their consideration of the cost and working of the various systems.

Mr. W. B. LAMPARD described a model of his apparatus for charging inclined gas retorts, and said that this apparatus was especially adapted for use in connection with double settings was extremely simple, and designed with a view to simplicity, being constructed upon the roller friction principle, and there being no delicate parts whatever belonging to it.

Replying to a question by the President, Mr. Lampard said the apparatus had not yet been in actual use.

Mr. J. BRAIDWOOD said that at his works they had been working inclined retorts for about eight months, and the only difficulty they had found all through had been with the heating. He thought that when once the heating was satisfactory there would be no more difficulty with inclined retorts than with ordinary horizontal retorts. He would rather work inclined retorts, not only because of the saving effected, but because any man who was put to it could, in the course of a couple of hours, do as well as a man who had been at it for some months. They had had no difficulty from roughness of the retorts. They overheated some of them, and put them into a peculiar shape, but they charged them now just as easily as the level ones. They were not very particular about setting them exactly level. He had departed from the angle of 30°. Perhaps that was one of the reasons of his success. He set them all at 36°, and retarded the rate of the delivery of the coal by means of an apparatus in the scoop. They were working now about 150 tons a week, at the rate of about 1*s.* 7½*d.* or 1*s.* 8*d.* a ton, instead of 3*s.* 4*d.* which was the cost of the hand work.

Mr. WEST said that the subject was a very old one with him, and he was very pleased to find it brought before such an important association. The question of stoking machinery for drawing and charging gas retorts, as many of them knew, had been introduced many times; and he had been labouring and thrashing away at it for many years. Yet engineers required educating. There were certain things yet that required to be done, but which some of them had not done. The author had indicated some of the improvements which engineers might make to render the work of the machinery more perfect. One important matter was that the mouthpieces of the retorts should not be contracted. It was a very important matter indeed. If the machinery was perfect the more objection there was to the contraction. If there was contraction a piece of coke would get jammed in the mouthpiece, with the result that there would be a very great strain thrown on the machinery. If the mouthpieces were parallel, or slightly larger than the retort, the coke would come out very easily indeed. Contraction of the mouthpieces had smashed up more machinery than anything else had done. It was something like drawing a cork out of a bottle. He hoped that those engineers who were not yet using machinery would put parallel mouthpieces upon their retorts when they were making alterations, so that machines could be satisfactorily employed. He did not quite understand the point about the cost. Mr. O'Connor seemed to think that there was some disparity between his, Mr. West's, statement as to cost and those of other people. All that he could say was that a very short time ago he sent round to several gas companies, and asked them if they would give him the result of several years' working. He sent to those who had had the machinery for very many years, and he believed that he got the facts, because he was bound to say that, as a rule, inventors did not get more credit than they were entitled to. He therefore objected to the 10*d.* because he had several detailed statements from gas companies showing that the saving was 50 per cent. more than 10*d.* per ton. At Maidstone, where the machinery had been working many years, the cost of stoking was 1·43*d.* per thousand, or 1*s.* 3·75*d.* per ton. Comparing that with what it would cost for hand labour with the ordinary system, there would be a saving of from 1*s.* 2*d.* to 1*s.* 3*d.* They had to say what it would cost on the old system of working, and they had to assume that figure; but he was told by M. Valon and most of the engineers who were working in the southern districts that he had taken too low a figure. After taking that low figure, he found that the saving at Maidstone on the whole of the carbonising was 1*s.* 2¾*d.*; at Tunbridge Wells, 1*s.* 0¾*d.*; at Ramsgate, 1*s.* 3*d.*, and at Folkestone, 1*s.* 2*d.* Therefore 10*d.* was not correct. Another point was the question of the saving of 10*d.* at Birmingham, where the Ross drawing-machine was only at work. He had seen it at work that afternoon. He did not know whether the author was aware that he had a large number of compressed-air machines at the Saltley works, which had given so much satisfaction that at the present time he had orders for four more. The amount of saving in various districts varied according to the size of the works. There was no doubt whatever that the manual machine was most suitable for small and medium-sized works. He did not quite agree with his friend Mr. Valon that it was preferable for use in larger works. Where they had a very large number of retorts to operate upon there would be a great advantage in using the power-machines. Of course, the machines had not all been perfect, and he was not quite sure that they had all been handled properly. The machines worked more perfectly in one place than another, and they saved more in one place than another; that was not the fault of the machines, but the fault of those that handled them. He had had the same type of machine at work in several places, and in some it had produced very large savings, and in other places it had not done its work so well, and had not produced so much saving. Much depended upon local conditions, and perhaps upon the arrangement of the retort-house. Retort-houses were certainly better when they were properly designed and arranged for the machinery in the first instance. Something had been said about breakdowns; but he thought that a machine which worked night and day, Sunday and all, must be expected to break down at some time: it wanted a rest and a little looking at. Mr. Valon had said that his machine went on year after year, and that he only had to attend to it on two or three occasions. He, the speaker, thought that if an engineer had to stop for a few hours on a week-day or on a Sunday it was not much to speak of. He did not think that engineers had much to fear from breakdowns, and the more they applied machinery the more would that fear vanish. At Manchester, where he was chief engineer for many years, they worked with machinery entirely; they made in one of their works eight million cubic feet per day. They never had any serious breakdown, and they never charged any retorts by hand. Everything that went wrong was rectified in a very short time. Of course they gave proper attention to the machinery, as they would to any ordinary engine. He was glad that Mr. Tysoe had given him such a favourable report upon the machinery at East Greenwich; it was working on 300 mouthpieces, not 150. Mr. Tysoe meant through retorts. They would find there that the saving of men was very considerable, and the saving in money was 11*d.* per ton on the present number of retorts, which might be increased. The time of drawing and charging the retorts was about one minute per retort, sometimes less. It could be done in less time, but he did not advocate that it should be. One minute was a very short time, and if it was done in much less time the work was not done quite so well. He thought, with Mr. Valon, that the time had now come when everyone should consider the propriety of having machinery of some kind or another.

He did not propose to go into the question of inclined retorts *versus* horizontal retorts, as most of those present knew his views on that point. He still adhered to the idea that the horizontal system was the best. He did not intend touching upon that point, but Mr. Van Vestrant intimated that the machinery was expensive. He, the speaker, was bound to say that if he were to fit up a large retort-house upon the horizontal system with his machinery it would cost considerably less than it would on the inclined system. He might say that his son had just returned from Melbourne, where he had been for the last twelve months erecting machinery of a similar kind to what had been put up at Greenwich; and they had produced at Melbourne on the average 8000 cubic feet of gas per mouthpiece, the saving being 2*s.* 2*d.* per ton, and the saving at Sydney was 3*s.* 6*d.* per ton. He was glad to say that engineers abroad appreciated machinery when they got it, and it appeared to him that they studied the things, and knew as much about them as engineers here did. When Mr. Bush went out to Australia he did not have any skilled men to put up the machinery or to work it. He took men from the quay, and in a very short time made them efficient. His, Mr. West's, son said that they were doing their work most skilfully. The size of the retort is 21 by 15, and is 10 feet long. The coal there in use would produce about 10,000 cubic feet per ton.

Mr. O'Connor thanked the meeting for the kind way in which they had received his paper. He said that Mr. Gandon had remarked upon the fact that the machinery might break down sometimes, and that therefore it was well not to rely entirely upon it. A reserve of machinery of all kinds was required to some extent, but machinery for a place like a retort-house should be of so simple a kind that it would not require more than very easily executed repairs. According to Mr. Valon, one or two days in the course of a year was quite sufficient to put the machinery in order. Mr. Gandon had also alluded to Mr. Braidwood's system. He, the speaker, believed that the hydraulic main might be placed at either end. It was not settled whether it was better to place it at the top or at the bottom. Whether the gas should pass upwards or downwards was not quite decided. He thought that success was likely to come to that system which required the least complicated machinery. With regard to his not mentioning Mr. Kitt's invention, he might say that his paper was not upon the arrangement of retorts, but aimed rather at describing the mechanical means suggested for charging them. Mr. Tysoe had spoken upon the figures that he 'the author' had given as to the cost of drawing by machinery and charging by hand. He had obtained his information direct from Mr. Hunt some few months ago. With regard to Mr. West's remarks about the cost, he noticed that several of the speakers at the Ryde meeting were not quite agreed as to the exact saving, and it occurred to him that the real cause of this was that they had been working upon a different basis, and he had suggested that in his paper.

Plate 1.

Fig. 9.

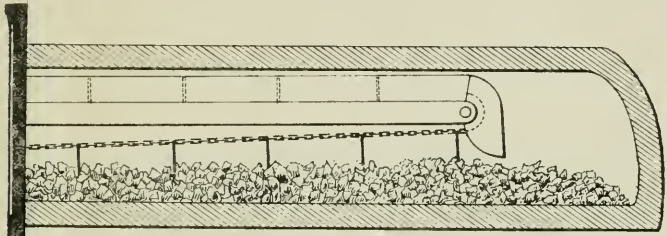


Fig. 10.

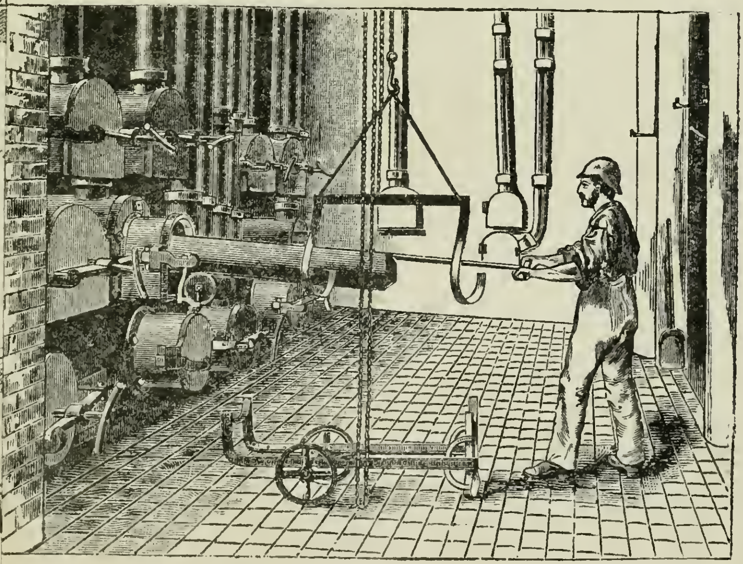


Fig. 1.

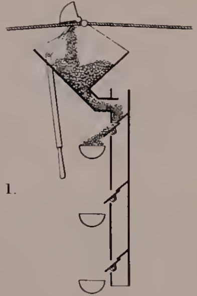
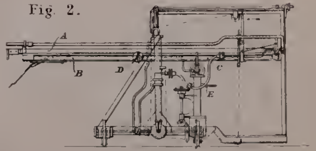


Fig. 2.



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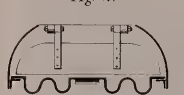

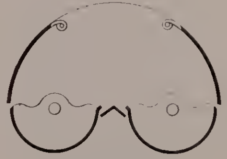

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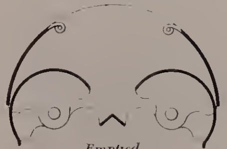

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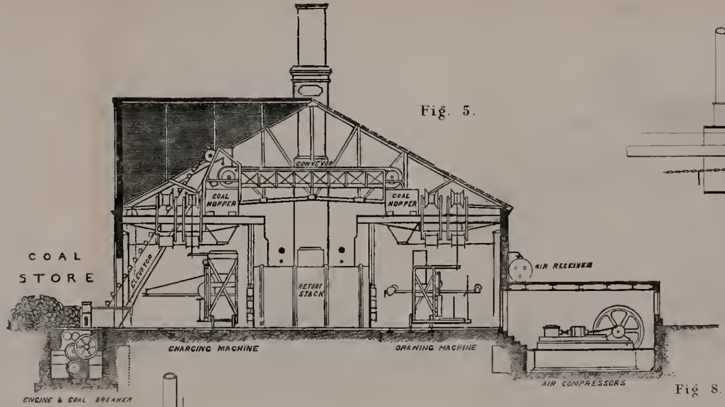
Fig. 4.

Fig. 5.



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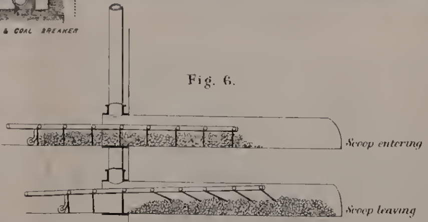
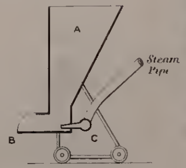


Fig. 7.

Rake Rod

Fig. 8.



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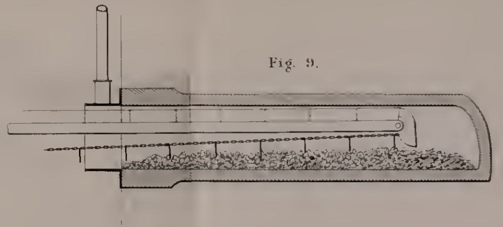

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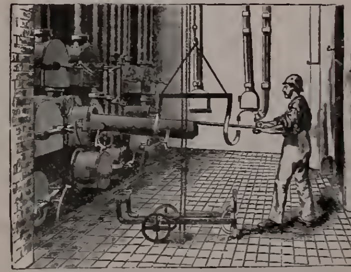

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Plate 2.

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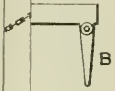

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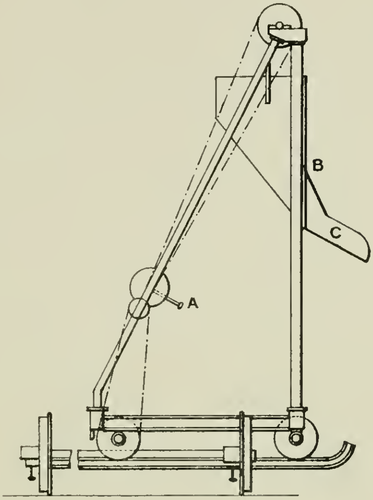

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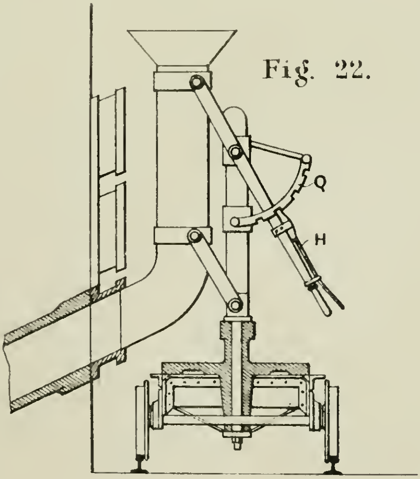

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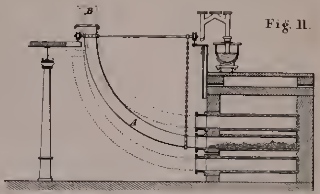

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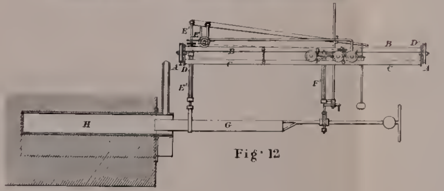


Fig· 12

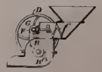


Fig 14

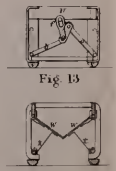
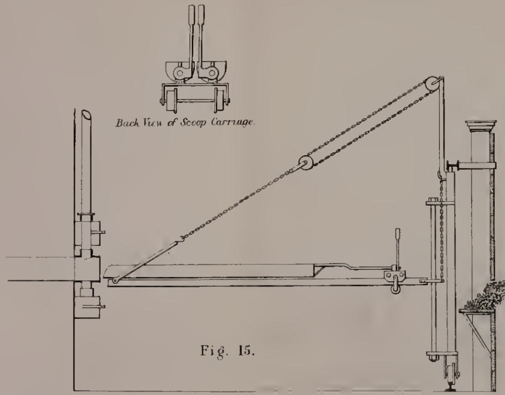


Fig. 13



Back View of Scoop Carriage.

Fig. 15.

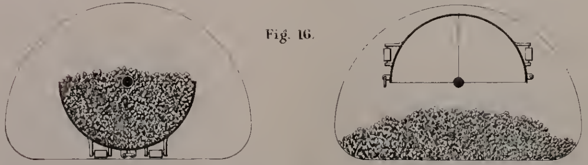
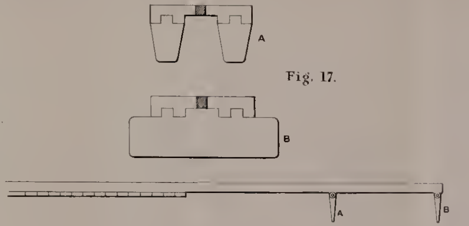


Fig. 16.



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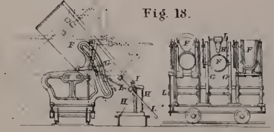

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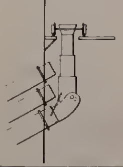

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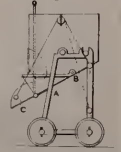
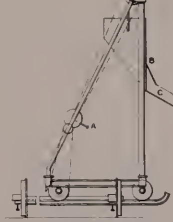


Fig. 20



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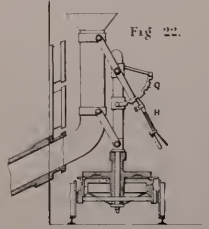

Fig 22.

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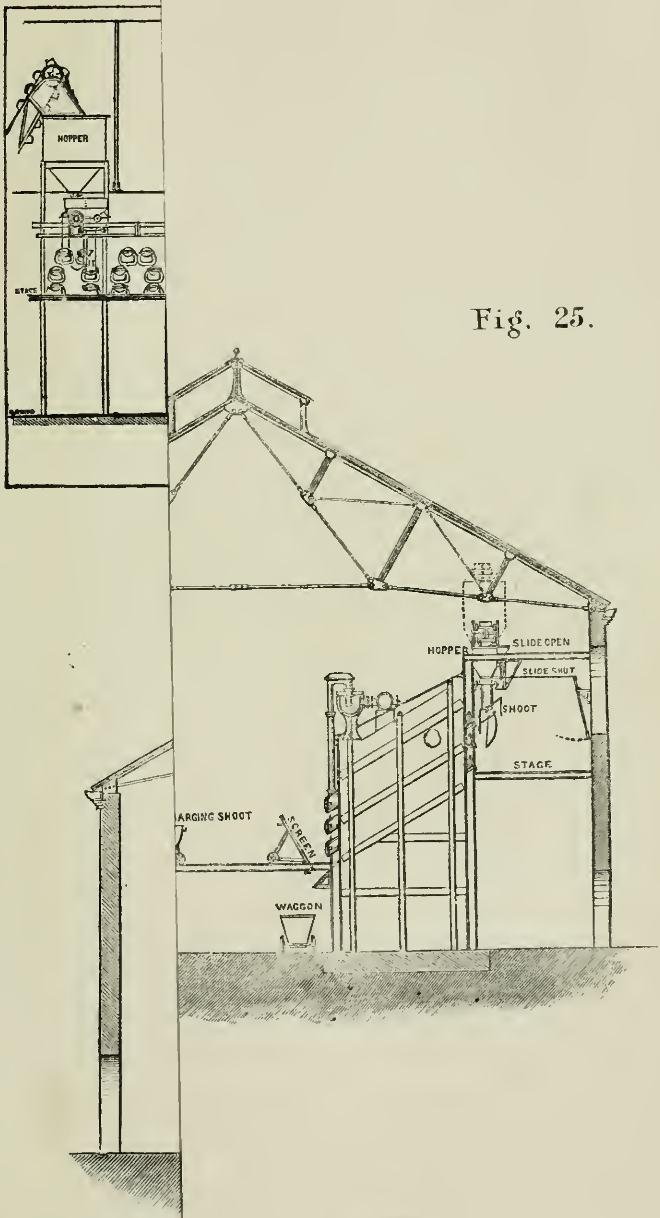
Plate 3.



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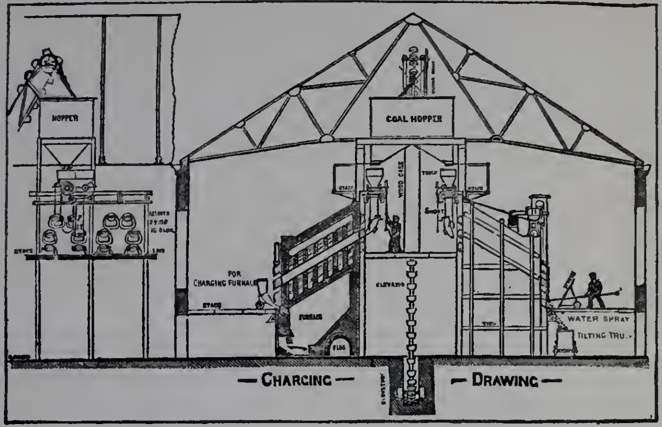

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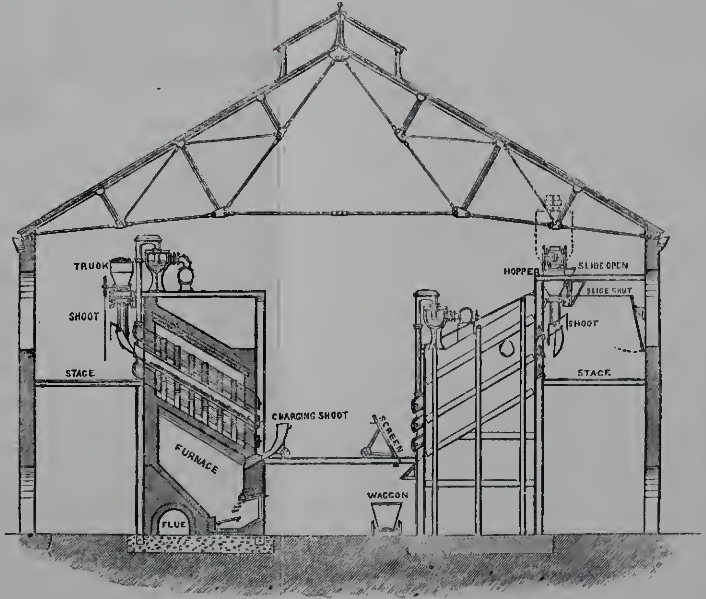

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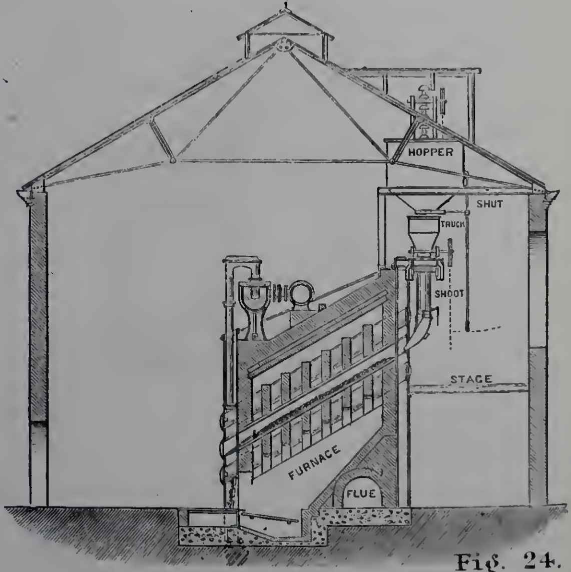

Fig. 24.

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November 2nd, 1891.

W. N. COLAM, President, in the Chair.

CORROSION IN STEAM BOILERS.

By James Hugh Paul, B.Sc.

The term "corrosion," as applied to steam boilers, means the wasting away of the tubes and plates, and with the exception perhaps of that form known as grooving, it is entirely a question of chemical reactions.

If a boiler plate were a homogeneous mass of pure iron, and if feed-waters were merely pure water, only one question would have to be considered, viz. the action of iron upon water at various temperatures and pressures; but as a boiler plate is not a homogeneous mass of pure iron, and feed-waters always contain dissolved substances, the subject is further complicated by the character and structure of the plate, and by the varied character of the impurities of natural waters, so that the question really resolves itself into what action a given iron has upon various chemical solutions? for it may be taken as an axiom that a natural water will either scale or corrode a boiler, or possibly do both.

It will be necessary then to follow the plate chemically through the various processes it undergoes during manufacture, and to devote a portion of the paper to the characters of natural waters.

Pure iron is a metal capable of existing in two allotropic conditions. At ordinary temperatures pure iron is a soft white magnetic metal (α iron); at temperatures above 855° C. the same iron exists in another form, that is, in the hard non-magnetic state (β iron). If the iron contains certain other elements, a portion of the molecules of the iron can be permanently retained in the β condition, and a hardened form of iron called steel is the result. If steel be again heated above 855° C. (1570° Fahr.), and allowed to cool slowly, the iron returns to its original or soft condition. The principal elements which enable the iron to be permanently retained in the hard condition are carbon and manganese; if the proportion of manganese be large the whole of the iron is retained in the

β form however slowly the mass is cooled, and the iron remains intensely hard and non-magnetic. Besides assisting the iron to retain the β form, the carbon can also exist in two distinct forms, the one in combination with the iron as carbide of iron, and the other as hardening carbon, that is in a state of solution in the iron. Above 660° C. (1220° F.), the carbon is in a state of solution, and if the metal be suddenly cooled, the carbon remains in the form of hardening carbon; if the metal be slowly cooled, the carbon enters into combination with the iron to form carbide of iron, which has little tendency to harden the iron, hence the metal becomes soft. The carbide of iron so formed is mechanically mixed with the crystals of metallic iron, and its appearance after etching with a solvent, is granular. Hardening carbon separated by a solvent is quite black and amorphous, the etched surface has a uniform black appearance, and the separated carbon is easily washed off. Annealing consists in heating the steel to a certain temperature and allowing it to cool slowly. Tempering consists in heating to a temperature much lower than that for annealing, and then generally cooling rapidly. During tempering the β iron returns to the a condition and the hardening carbon to the carbide form, but the carbide of iron is formed *in situ* in a solid and not in a plastic mass, so that it remains in a very fine state of division, and when separated from tempered steel it is left in the form of a dull amorphous powder, while the carbide from annealed steel of the same composition is left in brilliant metallic spangles.

Phosphorus, silicon, and sulphur, tend to prevent the molecular change in the iron, and therefore maintain the iron in their immediate vicinity in the a form, whereas in their absence it would assume the β condition. Hence these elements have a tendency to render the iron soft and malleable.

Chemical Properties of Iron.

Finely divided iron prepared from iron amalgam takes fire on exposure to air, and decomposes water at 100° C. (212° F.), with the evolution of hydrogen. Ordinary iron is an easily-oxidisable metal, though not nearly so active in the mass as in the finely divided state. It readily undergoes atmospheric oxidation at ordinary temperatures, and becomes converted into a red mass of ferric oxide. Both moisture and carbonic acid are necessary to promote this oxidation to its fullest extent, but both of these are present under the normal conditions of ordinary oxidation. Rusting or corrosion goes on more rapidly if carbonic acid be present, but also goes on in its absence. In ordinary cases an unstable bi-carbonate of iron is first formed, which is easily decomposed into ferrous hydrate, a substance that has a great affinity for oxygen, which it rapidly absorbs, forming yellow ferric hydrate. This is the yellow rust formed in damp or wet places ($Fe_2 O_3 3 H_2 O$). When the amount of moisture is small, red ferric oxide only is formed, and between these limits the amount of moisture will regulate the colour and composition of the rust, which may consist of a variable mixture of ferric hydrate with ferric oxide. Here is an analysis of a solid mass of rust taken from a thoroughly rusted iron railing in Kirkwall, Orkney. Although the rusting has not taken place in water, the climate is damp and humid:—

Analysis of Rust. Kirkwall.

Ferric hydrate ($Fe_2 O_3 3 H_2 O$)	70·02
Ferric oxide	26·70
Ferrous oxide	2·22
Ferrous carbonate	·42
Silica	·16
Carbon	trace
Phosphoric acid	trace
	99·52

Iron sealed up in water, without air, becomes coated with a thin film of black oxide of iron, and eliminates a small quantity of hydrogen, but the oxide seems to protect the iron from further oxidation.

At ordinary temperatures pure dry oxygen is without action on iron, but at a temperature of 230° C. (446° F.), oxygen is absorbed, and unites directly with iron to form a thin film of the magnetic oxide. At a red heat the action is more rapid, and a thick coating of smithy scale (magnetic oxide) is formed, and if the iron be raised to a white heat in oxygen gas, it burns and forms a fused globule of magnetic oxide of iron ($Fe_3 O_4$).

Boiler plates and other articles of steel and iron that are worked at a red heat have a coating of this scale oxide, that protects them from further atmospheric oxidation, but when any portion of the iron becomes exposed, the magnetic oxide seems to act as a separate metal, an electrolytic action takes place, and the corrosion of the iron goes on more rapidly at that spot, than it would do had the iron not been coated. This is more especially the case in saline solutions, as an electrolytic couple is started and the iron is very rapidly attacked.

At ordinary temperatures, and in the absence of oxygen and carbonic acid, iron is without action on water, but if the iron be heated to redness and steam be passed over it, the steam is rapidly decomposed and hydrogen is liberated; while the oxygen converts the iron superficially into the magnetic oxide. This process is now worked industrially to give iron articles a protective coating. So long as the surface is preserved intact, the protection from atmospheric ravages is perfect.

Pure gaseous carbonic acid is without action on iron below 400° C. (752° F.), but at this and higher temperatures the action is very considerable, as the iron is converted into ferric oxide and carbonic oxide is formed, and at a red heat the carbonic oxide itself is further decomposed by the iron, yielding oxide of iron and carbon. This is probably the cause of the lamination that often takes place in boiler plates, as the liberated carbon will unite with the iron to form cast iron.

A solution of carbonic acid in water, like other acids, is decomposed by iron with the liberation of hydrogen, and if atmospheric oxygen be kept away, the solution remains colourless, as the ferrous carbonate formed is soluble in excess of carbonic acid, forming a soluble bi-carbonate of iron. If oxygen is allowed to come into contact with it, this salt is converted into ferric hydrate, which is thrown down as a yellow deposit. This is the action that takes place with many natural waters containing iron. Before they come into contact with air they are perfectly clear and colourless, but on exposure they soon throw down a brown deposit, and form a thin brown pellicle on the surface.

Alkalies, to a certain extent, prevent the rusting of iron; this is true with pure water within certain limits, but if the water contains a certain amount of the chlorides of the alkalies, the rusting is not prevented by the presence of the alkali, in fact iron corrodes more readily in an alkaline water containing chloride of sodium, than it does in pure water. Water drawn from deep wells is often of this character, that is charged with carbonate and chloride of sodium. These artesian well waters have a very corrosive action upon iron, and in many cases have to be specially treated to enable them to be employed for any ordinary purpose in which they are brought into contact with iron.

Caustic soda itself has a solvent action upon iron, and very considerable quantities of iron are taken up by caustic soda and converted into oxide of iron by the action of the air. A strong solution of caustic soda allowed to act on wrought iron for 216 hours removed as much as 1·7 per cent. from steel ·54 per cent. and from cast iron 1·4 per cent., while another authority states that by blowing air through a 30 per cent. solution of caustic soda contained in an iron vessel a considerable quantity of iron dissolves without colouring the solution. After standing for some time, or on dilution, the solution becomes red from deposited ferric hydrate. (The iron is supposed to be in the form of ferrate.)

All forms of iron are rapidly corroded by mineral acids, and except in the case of nitric acid, with evolution of hydrogen. The iron has the property of absorbing or occluding this hydrogen to the extent of as much as 250 times its own volume. This occluded hydrogen changes the character of the iron, causing it to become hard and brittle, and this action may sometimes be the cause of explosions in steam boilers; the brittleness is caused whenever hydrogen is given off from a surface of iron either in an acid or in an alkaline solution. Prof. Ledebur states, "In the third experiment each of the wires was connected with a heavy block of zinc and then dipped in an acid. A rapid evolution of hydrogen took place over the whole surface of wire. After three hours these were taken out and tested. This and all other experiments made by the author showed that the brittleness increased more rapidly when the iron was in contact with zinc than when no zinc was used." This is disputed by Howe, but whichever view is taken it is certain that in every case in which hydrogen is evolved from the surface of iron or steel, the physical nature of the metal is changed and it becomes brittle.

Iron has also the property of occluding other gases, such as nitrogen, carbonic oxide, carbonic acid, &c., and various amounts of these gases are absorbed by iron and steel during the process of manufacture. In one experiment made on steel the sample was found to yield about 10 times its volume of gas, having the following percentage composition:—

Carbonic acid	16·55
Carbonic oxide	24·35
Hydrogen	52·61
Nitrogen	6·49
	100·00

Hydrogen is more soluble in cast iron than is carbonic oxide, but its solubility is diminished by phosphorus and silicon. Steel retains its hydrogen more forcibly than cast iron, but soft iron retains carbonic oxide more forcibly than it does hydrogen. Iron rich in carbon takes up gases consisting chiefly of hydrogen, and iron poor in carbon, especially combined carbon, takes up gases in which carbon predominate (Ledebur).

Manufacture of Boiler Plates.

Steel and wrought iron are modifications of pure iron containing small percentages of carbon, silicon, manganese, phosphorus and sulphur, and practically there is no chemical difference in the composition of a boiler plate made of mild steel or of wrought iron.

Analysis of Boiler Plates.

	Wrought Iron.	Wrought Iron.	Soft Bessemer Steel.	Soft Siemens-Martin Steel.
Iron	99·20	99·540	99·300	99·224
Carbon	·04	·301	·130	·200
Manganese	·17	·064	·468	·500
Silicon	·15	·049	·023	·009
Sulphur	·03	·016	·031	·035
Phosphorus	·21	·030	·032	·037
Loss, &c.	·20		·011	
	100·00	100·00	100·00	100·00

It is exceedingly difficult to say where steel begins or wrought iron ends, and the difference seems to be in the molecular arrangement of the particles.

Bessemer steel is prepared from pig iron by blowing air through the molten mass until the impurities, more oxidisable than the iron, are nearly eliminated; suitable quantities of manganese and carbon are then added, and the metal cast into ingots. On cooling, the iron shows a further tendency to rid itself of the impurities, and the ingot is not uniform in quality, the crystals of comparatively pure iron separate first, while the impurities tend to concentrate in that portion last solidified. The top, therefore, is the most impure, and has to be cut off and rejected, while the purest iron will tend towards the sides and bottom of the ingot. An ingot of steel may therefore be regarded as a mass of crystalline molecules of iron embedded in a more fusible matrix of iron alloys. The ingot is cut into suitable pieces heated to a bright red heat, and at that temperature rolled and hammered until the desired size and thickness of plate is attained. So much depends on the thermal treatment of the metal, that some specifications for boiler plates distinctly state "that the ingots shall be at least 20 times the thickness of the finished plate, and that no steel for boiler plates shall be rolled, struck with a hammer, or otherwise worked at a black heat, that is between 750° F. and 950° F." The whole of the work is performed on the plate at a temperature above 1000° F., and while the metal is in a plastic state, it is afterwards allowed to cool slowly, so that the iron changes to the soft (a) form, and the carbon takes the form of carbide carbon, but as the whole of the molecules of the iron are never converted into the soft form, and the whole of the carbon never enters into direct combination with the iron, the finished boiler plate is a mass of very complex and complicated structure. There are the molecules of soft iron, molecules of hard iron, molecules of hardening carbon, molecules of carbide of iron, all embedded in a matrix of more or less uniform alloys of iron, phosphorus, manganese, sulphur, and silicon, and all these have been welded together while the mass has been in a plastic state. As iron absorbs oxygen at a red heat, the plate is further complicated by the presence of a more or less superficial layer of magnetic oxide of iron.

Wrought iron is also prepared from cast-iron by removing a certain quantity of the impurities that exist in the pig iron. This is performed by puddling, the essential of the process being the oxidation of the greater part of the carbon, phosphorus, silicon, and sulphur. In puddling the oxygen is supplied by the oxide of iron, in which the bars are heated for a period sufficient to complete the process; the purified iron assumes a pasty form, but never melts, so that much of the slag has to be removed by squeezing out at a high temperature under the steam hammer. This process is continued several times, the bars are cut up into smaller pieces, tied into bundles, heated, rolled, and hammered until the slag is squeezed out, and the mass assumes a fibrous structure, and not only are the plates themselves not homogeneous, but the boiler is built up of dissimilar plates, stays, rivets, and bolts, and is provided with fittings made of entirely different metals, such as copper, tin, lead, &c.

Taking all these things into consideration, a boiler plate of steel or iron is a very complicated piece of mechanism to deal with, both chemically and physically, for not only has the chemical nature of the iron and its alloys to be considered, but the molecular arrangement and physical structure of the mass has also to be taken into consideration. Chemically it cannot be considered homogeneous; metallurgists may so regard it and call their mild steel homogeneous; it may be homogeneous from their point of view,viz. in its apparent texture and fracture, but from a chemical standpoint it cannot be so regarded; small wonder then that when it is brought into contact with a corroding agent, the corrosion is very unequal, one part of the plate being almost untouched, while another portion is so deeply pitted and hollowed, as to be nearly perforated. There must necessarily be streaks and patches of the different alloys, and of the different forms of iron, without considering particles of slag and scale oxide, and all these conditions in conjunction will determine the lines along which the corrosion will take place, which will be along the line of weakest resistance to the corroding agent. Water in its action upon crystalline masses of soluble substances, such as salt or loaf sugar, furnishes a familiar example.

A block of salt is a collection of crystalline particles, and is analogous in structure to an iron plate. If the block be placed in a quantity of water insufficient to dissolve the whole of it, a portion will rapidly dissolve, but the block will not be evenly attacked; fissures will rapidly show where the water has had the most solvent action—that is, which particles have first yielded to the solvent action of the water, and will probably be those crystals which are in the finest state of division, or those which are mixed with the chlorides of calcium or magnesium, as commercial salt is never pure, leaving the harder, purer, larger, and better formed crystals to longer withstand solution. In places the block will hardly be attacked at all, whereas in others fissures will extend right through into the centre of the mass. Like a steel plate, the salt slab is formed by slow cooling from a liquid state, and like the former consists of a mass of fine crystals.

Anyone who has witnessed the corrosion of a boiler-plate will readily understand how some portions are regularly eaten away, while other parts are barely touched. Did corrosion take place evenly over the whole surface of a boiler, corrosion would not be one-tenth part so destructive as it really is; for there would be an equal, and therefore much less, action on any one part of the boiler. The boiler would gradually, but evenly, get thinner, whereas at present the strength of the boiler rapidly diminishes, for its greatest strength is the strength of its weakest part. To say that corrosion follows no rule is neither true nor scientific, for it does follow some rule; it flows along the line of least resistance to the corroding agent; and to talk about the vagaries of corrosion is merely another way of saying that the molecular arrangement of the particles cannot be seen, and that it is therefore impossible to say where the most soluble particles lie, or, in other words, to foretell the particular spots where most solution will take place. Metals are collections of molecules massed together by fusion and pressure; they are never perfectly pure, and their structure is entirely altered by the treatment they undergo, and the very fact of their being very seldom found free in nature points to the conclusion that, in their isolated condition, they are in a state of unstable equilibrium, and are ever ready to enter into fresh combinations—that is, to corrode. It is only those metals that are found free in nature, such as gold and platinum, that are able to resist ordinary corroding influences.

The foregoing is a chemical history of the boiler-plate; and it will now be necessary to turn to another side of the question, and deal with the corroding agents that are likely to be brought into contact with the boiler-plates. These plates, under ordinary circumstances, are the media through which the heat of the coal is driven into the water, and waves of energy are more or less continually passing from the heated fuel on the one side to the comparatively cool water on the other side, so that the plate is liable to corrosion on both sides; on the outside by the action of the carbonic oxide, carbonic acid, and sulphur of the fuel, and on the inside by the action of the water and its dissolved impurities.

Corrosive Natural Waters.

The source of all natural waters is the sea, the atmosphere being the agent of transportation, whereby the more or less pure water evaporated from the ocean is brought into more or less intimate contact with the many soluble substances with which the air is contaminated.

Rain-water evaporated from the sea contains chloride of sodium, the finely divided particles of which are collected from the spray thrown up by wind and storms.

An Analysis of Rainwater, as evaporated from the Sea.

	Grains per gallon.
Nitrate of ammonia	·043
Sulphate of soda	·339
Chloride of sodium	5·460
	5·842

In its passage over the land the character of the rain-water is very much modified. Ammonia, which is an almost constant constituent of the air, becomes dissolved, and is neutralised by small quantities of sulphuric and nitric acids, that also find their way into the air from terrestrial and atmospheric sources; so that rain-water deposited in country districts a long way from the sea contains small quantities of these salts, in addition to chloride of sodium.

An Analysis of Rainwater falling in an Inland County about 100 miles from the Sea.

	Grains per gallon.
Nitrate of ammonia	·078
Sulphate of ammonia	·227
Sulphate of soda	·442
Chloride of sodium	·447
	1·194

When the rain-clouds pass over manufacturing districts, where quantities of coal and coke are burnt, much sulphuric acid passes into the air, and finds its way into the rain-water; so that rain-waters in certain districts are liable to be acid, as both hydrochloric and sulphuric acids are amongst the products of combustion from furnaces burning coal and coke.

Rainwater at Manchester.

	Grains per gallon.
Hydrochloric acid	·408
Nitric acid	·094
Sulphuric acid	·260
Sulphate of soda	3·452
Sulphate of ammonia	1·602
	5·816

Rainwater at Glasgow.

	Grains per gallon.
Hydrochloric acid	·628
Nitric acid	·199
Sulphuric acid	·211
Sulphate of soda	4·305
Nitrate of ammonia	2·465
	7·808

Coal contains on an average at least 1 per cent. of sulphur, and the complete combustion of this quantity means this, that every ton of coal burnt gives rise to 67 lbs. of sulphuric acid; and a blast furnace consuming 100 tons of coal per day will pour into the atmosphere 3 tons of sulphuric acid in that time. Hence the liability of rain-waters to become very acid in manufacturing centres.

Fortunately the air contains a considerable quantity of atmospheric dust (·006 grammes per cubic metre in Paris), consisting principally of organic matters, with carbonates of lime and magnesia. This dust, containing a considerable percentage of carbonates, tends to neutralise these acids, sulphates of lime and magnesia being the result; and thus, except in the very centres where much coal is burnt, the rain-water is rarely acid, and if collected even a short distance away becomes alkaline again.

Atmospheric Dust.

Oxide of iron	6·12
Carbonate of lime	15·94
Carbonate of magnesia	2·12
Silica	34·33
Chloride and sulphate of soda	9·22
Organic matter	32·27
	100·00

This formation of sulphate of lime in rain water accounts for the fact that of over 500 samples of natural water analysed by the author not one was found to be free from sulphate of lime. Ammonia is also one of the products of the combustion of coal and of the decomposition of organic matter; and it is further possible that the ozone and hydrogen peroxide contained in air act in such a way as to form ammonia, which will further tend to neutralise these acids.

Snow collected on Grass, London, S.W.

Sulphate of lime	1·29
Sulphate of magnesia	·31
Oxide of iron	·11
Sulphate of soda	·48
Chloride of sodium	·43
Chloride of ammonium	·87
Nitrate of ammonia	·10
Carbonate of ammonia	·13
Organic matter	·20
	3·92

Rainwater collected during Thunderstorm, London, S.W.

Sulphate of lime	1·56
Sulphate of magnesia	·17
Sulphate of soda	·60
Chloride of sodium	·08
Chloride of ammonium	·86
Carbonate of ammonium	·10
Oxide of iron	·08
	3·45

Most rain-water before coming into industrial use falls upon the land, and finds its way through more or less permeable strata, and becomes neutralised by the carbonates nearly always present, and of course, becoming charged with lime salts, becomes an incrusting water. Where there are no carbonates present in the soil, as is sometimes the case with ferruginous sands, the water remains acid, and contains iron salts. Sometimes the strata contain iron pyrites and peaty matters, and in that case the water becomes a corrosive water of the worst description.

Water from shallow Well in Grey Sand.

Sulphate of lime	22·50
Chloride of magnesium	11·45
Sulphate of sodium	22·52
Sulphate of iron	10·85
Silica	2·83
Organic matter	3·07
Peaty acids	6·16
	79·38

The corrosive deposit taken from the tubes of a boiler evaporating this water shows a large quantity of iron and traces of copper derived from the fittings. The sulphate of lime scale deposited from this water is intimately mixed with a fine vermilion coloured powder, consisting principally of a basic sulphate of iron.

Corrosive Deposit. On tubes.

Copper	trace
Sulphate of lime	6·36
Sulphate of magnesia	18·15
Sulphate of soda	23·48
Chloride of sodium	18·13
Oxide of iron	14·00
Silica	5·31
Organic matter	11·32
Moisture	3·25
	100·00

Red Scale.

Sulphate of lime	83·05
Basic sulphate of iron	10·74
Silica	6·21
	100·00

This boiler had evidently been worked a considerable time without blowing off, as will be seen from the large amount of soluble soda salts in the corrosive deposit. The water must have been getting nearly saturated with them. When this deposit was treated with hot water to dissolve out these salts and then analysed, it showed 60 per cent. of oxide of iron and a trace of copper..

Analysis of washed Deposit.

Oxide of iron	60·18
Silica	18·63
Organic matter	21·19
	100·00

Similar waters are found in many pits and collieries, and are mainly contaminated by the atmospheric oxidation of the pyrites in the coal.

When rain-water, either acid or alkaline, penetrates peat bogs the water becomes brown and acid. The town supply of Lerwick (Shetland) is of this character, and is quite brown. Viewed in large volumes the colour is so deep that it looks black, and it contains a large quantity of free peaty acids. Such a water would be highly corrosive.

Peat Water. Island of Noss, Shetland.

Chloride of calcium	1·97
Chloride of magnesium	3·09
Chloride of sodium	6·05
Oxide of iron	·47
Silica	1·12
Organic peaty acids	11·90 (= 3·43 sulphuric acid)
	24·60

When the collecting surfaces are hard non-permeable silicious rocks, very little is dissolved, and the collected water has all the characteristics of rain-water. These waters, when available, are generally adopted for water supplies because they are soft, and uncontaminated with sewage matter. Glasgow, Liverpool, Manchester, and Edinburgh are supplied with such waters collected from the rocky hills some distance away; but in the case of Huddersfield the rain-water is collected quite close to many large manufacturing centres, so that the supply collected from the rocky hills in the neighbourhood has been brought into contact with nothing to neutralise these acids; hence the town supply of Huddersfield is slightly acid. The amount of acid is, of course, variable in the water collected during different periods of the year, and also varies with the reservoir in which it is collected.

One analysis of Blackmoorfoot water shows ·46 grains of acid; the Longwood reservoir, taken at the same time, ·15 grains; the Wessenden ·33 grains free acid per gallon. Another sample of the Blackmoorfoot water, taken at a different time, showed ·18 grains per gallon of acid, while the water in the Cloughhead Reservoir was faintly alkaline.

HUDDERSFIELD WATERS SUPPLIES.

Blackmoorfoot Reservoir. Analysis A.

Sulphate of lime	2·94
Sulphate of magnesia	1·04
Chloride of magnesium	·18
Chloride of sodium	·85
Silica	·30
Oxide of iron	·29
Free hydrochloric acid	·46
	6·06

Longwood Reservoir.

Sulphate of lime	3·95
Chloride of magnesium	1·33
Silica	·59
Oxide of iron	·73
Free hydrochloric acid	·15
	6·75

Wessenden Reservoir.

Sulphate of lime	2·78
Chloride of magnesium	·73
Chloride of sodium	1·14
Silica	·23
Oxide of iron	·23
Free hydrochloric acid	·33
	5·44

Cloughhead Reservoir.

Sulphate of lime	3·91
Carbonate of magnesia	·82
Nitrate of magnesium	·65
Chloride of sodium	1·64
Sulphate of sodium	·12
Silica	·30
Oxide of iron	·30
	7·74

These are the waters that were found to have corroded the boiler of the steam tramway engine to such an extent that an explosion occurred on June 3rd, 1891, killing one man and injuring thirteen others. Analysis A gives the composition of this water.

The Board of Trade inquiry elicited the following facts:—

"The boiler was made throughout of BBB Cooper's Yorkshire iron; the shell was made of one plate $\frac{1}{2}$-inch thick, the seam being lap-jointed and double rivetted with $\frac{3}{4}$-inch rivets.

"The fire-box was made of one plate $\frac{7}{16}$-inch thick, with its vertical seam welded. The uptake was $\frac{1}{2}$-inch thick. There were 79 Field tubes $2\frac{1}{2}$-inch external diameter, and $\frac{1}{8}$-inch thick.

"When constructed the boiler was tested by the makers to 300 lbs. to the square inch by hydraulic test, and 160 lbs. by steam. Its bursting pressure was calculated to be between 650 lbs. and 750 lbs., and it was constructed to withstand a pressure of 130 lbs., but it could safely be worked to 150 lbs. It came into the possession of the Corporation of Huddersfield at the end of 1885, and was by them used for the purpose of driving a locomotive known as No. 9.

"The boiler was cleaned out every three weeks and then inspected, for the purpose of seeing that the cleaning was properly done, and that, in fact, the boiler was clean.

"New tubes were put into the boiler on the 20th and 30th January, and also a great many on February 7th, so that this boiler was practically retubed during the first two months of the year. In February there was some leakage found close to the ring of the mouthpiece, and a piece of iron 12 inches by 6 inches was cut out, and a copper patch was fitted on. On the 17th April a half-inch copper plug was put into the fire-box, and on the 2nd May there was a copper patch 17 inches by 8 inches put on the left-hand side of the mouthpiece; and on the 2nd June three $\frac{3}{8}$-inch copper studs were put in the mouthpiece between the two patches.

"We are of opinion that these copper patches should not have been used except merely for temporary purposes, iron or steel being the proper material; but as they have nothing to do with the explosion we need not refer to them at length.

"For the last eight months the engine had been employed on a line where it was found convenient to feed the boiler with the water obtained from the hydrant at Crossland Moor, which water came from Blackmoorfoot reservoir. From August 24th, 1889, to October 13th, 1890, the boiler was idle, and during that time was full of water obtained from that reservoir.

"It is perfectly clear, therefore, that there was acid in the water, and that the acid has affected other boilers used by the Corporation on their tramways we have no doubt, because we have heard that within a short space of time five new fire boxes have had to be supplied, owing to the iron in the old ones having corroded by the action of the water."

"*We regard the question of feed-water as one of very considerable importance; we are of opinion that sufficient attention is not paid to it, and we desire to call the attention of boiler users to the importance of feeding their boilers with suitable water.*"

"It is important to observe that when the plate was drilled for the purpose of inserting the studs it was found to be only $\frac{1}{4}$ inch thick—its original thickness being $\frac{7}{16}$ inch."

The explosion was caused by the fire-box having wasted away to such an extent from corrosion, as to be no longer able to withstand the pressure of steam."

It will be seen that this boiler was continually giving way, and required constant repairs. The acids contained in the water corroded the iron so rapidly in certain places, that the parts had to be cut out and replaced by copper patches and plugs, and the whole of the tubes had to be replaced.

(The author exhibited a piece of the plate that actually gave way, and also another piece of corroded iron taken from a kitchen boiler evaporating the same water. The deep and unequal pitting is specially noticeable, the slightly corroded portions standing up in bold relief. See Plate I.)

The chemical action has been this, the acid in the water has dissolved the iron, forming a solution of chloride of iron, and probably also of sulphate of iron, for the deposit from another boiler using the same water shows the presence of basic sulphate of iron. The iron chloride, on continued boiling at a high temperature and pressure has been decomposed and ferric oxide deposited, mixed with the sulphate of lime thrown down from the water at the high temperature reached in the boiler.

Corrosion Deposit. Blackmoorfoot Water. Analysis B.

Ferric oxide	57·52
Basic sulphate of iron	2·28
Sulphate of lime	38·47
Silica	1·48
Magnesia	·25
	100·00

M

The analysis B, is that of a deposit taken from another boiler using this water, and shows nearly 60 per cent. oxide of iron.

As the acid is poured into the boiler faster than it can corrode the iron, the water in the boiler becomes more and more acid. The boiler water after only three days run showed the presence of 1·53 grains of hydrochloric acid, or more than three times the original amount. Analysis C shows the components of this water.

Boiler Water (Blackmoorfoot) after three days.	*Analysis C.*
Silica	·45
Chloride of calcium	2·00
Sulphate of magnesia	1·53
Sulphate of soda	1·34
Sulphate of iron	1·39
Chloride of sodium	·18
Hydrochloric acid	1·53
Grease and organic matter	7·40
	15·82

Hence as time goes on the boiler water becomes more and more active, not only because the acid becomes more concentrated, but also because the corroded iron offers a continually increasing surface to the acid, and the exposed particles become more and more finely divided. The more finely divided the metal the more active it becomes. Iron in a very finely divided state decomposes water at a temperature of 212° F., whereas in the compact state it only does this at a red heat. And as this goes on a point is reached where the acid is no longer necessary to produce corrosion, the surface of the iron is in such an active condition that it decomposes the water itself. If a piece of iron that has been corroded by acid, is thoroughly washed and scrubbed to remove every trace of the acid, and then placed in distilled water a very large quantity of ferric oxide is very soon deposited, and if the wet plate is exposed to the atmosphere, oxygen is so rapidly absorbed that in a few seconds a thin film of ferric oxide is deposited, and is formed as rapidly as the film obtained when iron is raised to a tempering heat.

The statement in the Board of Trade Report, that the copper patches had nothing to do with the explosion, must be accepted with a certain amount of reservation. No doubt the corrosion was directly due to the acid in the water, and the explosion would have taken place sooner or later had no copper patches been put on, but as the copper patch was put on four months before the explosion, it must have increased the rapidity of corrosion. Two metals such as copper and iron placed in an acid solution form a galvanic couple, and the iron is more rapidly dissolved than it would be in the absence of the copper. Besides this the copper itself will corrode, for the author found 12½ per cent. of oxide of copper in a deposit taken from a similar boiler evaporating the same water. The sample was taken from near the flange of the boiler, at the end furthest away from the fire, where the circulation is least, and was taken out when the boiler was being broken up.

The following is the analysis of the above :—

Copper Deposit from Tramway Boiler. Analysis D.

Ferric oxide	35·34
Ferric hydrate	15·25
Bassic sulphate of iron	12·28
Oxide of copper	12·52
Silica	11·56
Magnesia	·80
Sulphate of lime	12·29
	100·04

ARTESIAN WELL WATERS.

As a rule artesian well waters contain very considerable quantities of soda salts. They are not usually considered to be corrosive waters, but in reality they are corrosive and attack both boiler and fittings.

Artesian Well. Analysis E.

Silica	·57
Bicarbonate of iron	1·14
Carbonate of lime	5·14
Carbonate of magnesia	1·51
Nitrate of magnesium	·06
Bicarbonate of soda	15·69
Sulphate of soda	21·71
Chloride of sodium	17·60
	63·42

The usual remedy for corrosion would be soda ash, and such was actually recommended by one boiler inspector—although such would be the very worst thing that could be used—the whole trouble arising from the presence of too much soda ash in the water. These soda salts must be kept down as much as possible by frequent blowing off and emptying the boiler once a month, otherwise the boiler water becomes highly charged with them. The lime and magnesia salts are precipitated in the form of a hard scale, a portion of the carbonate of soda is converted into caustic soda, and the water becomes so corrosive that it pits the boilers. The corrosion can only be kept down by blowing the boilers down three times a day and not running them for more than a month without refilling.

Analysis of Boiler Water after running One Month. Analysis F.

	Grains per gallon.
Caustic soda	163·24
Carbonate of soda	703·79
Sulphate of soda	1129·56
Chloride of sodium	1167·08
Nitrate of sodium	3·28
Organic matter	4·75
	3171·70

This water is in use at a certain hotel in London, and it is part of the imperative duty of the stoker in charge to blow down to a certain mark at stated hours during the day; this being checked by a very simple process worked out by the author, and capable of being worked by the engineer in charge, or even by an intelligent lad. After analysing the water taken from the boiler, it is easy to find out the relation between the chlorides in the water and the total amount of dissolved solid matter. Now chlorine is one of the easiest substances to determine quantitatively. It is done by a standard solution of nitrate of silver. The requisites are a graduated tube called a burette, a pipette, to contain 2 cubic centimeters, one or two cups or small tumblers, a solution of chromate of potash, and the standard solution of silver. The tumblers are marked with a file so as to show 100 cubic centimeters. The water is drawn from the gauge cocks, allowed to settle and get cool. Two cubic centimeters of the clear water are taken up by the pipette, transferred to the tumbler, which is then filled up with distilled or condensed water to the 100 cubic centimeter mark. A few drops of the chromate of potash are added, and the silver solution carefully run in, until the liquid assumes a permanent pink colour. The number of cubic centimeters of silver solution is then read off, and the strength is so regulated that the decimal point put two places to the right gives the total solids in grains per gallon. The method is very simple and the result obtained in a few seconds. The only difficulty is the preparation of the standard silver solution, which has to be prepared by a chemist, but a stock once laid in will keep and will last a long time.

A log of the total solids can be kept, and by running the eye over the numbers any marked discrepancy is at once observable, and non-observance of orders is at once detected.

The following is an extract from actual practice:—

Date	Boiler.	Grains per gallon.
July 3	No. 1	330
„ 15	„	1060
„ 18	„	360
„ 24	„	560
„ 27	„	430

It will be noticed that on the 15th the total solids stand at 1060. Enquiry elicited the fact that owing to a leaky joint on the blow-off pipe, they were unable to blow off all day. The boiler had to be laid-off and was started again on the 17th with fresh water. On the 18th the total solids were 360, and remained normal till the end of the month.

This method might readily be applied to marine boilers, and would at once indicate the amount of sea water getting into the boilers. It would be quite as easy as the salinometer, and more accurate, as it would absolutely measure the chlorides, which amount to over 90 per cent. of the total solids contained in sea water.

This question of boiler waters is a very important one and merits much more attention than has hitherto been bestowed upon it. The boiler water just alluded to would, in a two months' run, if never blown down, contain at least 20,000 grains of solid matter per gallon, and would in fact be a 30 per cent. solution of various soda salts. It need hardly be observed that this solution would be very corrosive in its action on steam boilers. If steam users paid more attention to this point, they would have a better knowledge of what was really going on in their boilers, and would know better what remedies to apply, instead of throwing in soda ash wherever pitting takes place.

Corrosion is oftener caused by alkaline than by acid waters. Acid waters are so searching in their action and make their presence so plainly manifest that the subject is thrust into view, but with alkaline waters the corrosion is more insidious and less evident, and steam users place such an absolute reliance on alkalinity that they cannot be led to believe that an alkaline water will cause corrosion.

Waters containing nitrates and nitrites become actively corrosive if allowed to become too concentrated in the boiler.

Nitrate Water.

Silica	·38
Oxide of iron	·17
Sulphate of lime	2·81
Carbonate of lime	·70
Nitrate of lime	·76
Nitrate of magnesia	·80
Chloride of sodium	5·77
Nitrate and Nitrite of sodium	9·11
	20·50

Nitrite of soda by continued boiling splits up into caustic soda and nitrate of soda, whereby the boiler water becomes very alkaline, and nitrous acid is set free to corrode the boiler and its fittings. Not only does the strong solution of alkali produced by continued boiling directly attack and corrode the iron, but in the presence of copper—the copper is dissolved and the nitrate converted into ammonia. Thus the copper of the fittings is dissolved and is then immediately precipitated by the iron of the boiler, an equivalent of iron passing into solution, in its turn to be precipitated as hydrate by the alkali in the water, hence the metals are rapidly corroded, the fittings become leaky, and a large quantity of oxide of iron is found floating about in the boiler water.

Boiler Water from above Water.

Caustic soda	143·50
Nitrate of soda	725·82
Chloride of sodium	458·64
Sulphate of sodium	264·38
Carbonate of soda	260·81
	1853·15

This water could be worked without any serious corrosion, provided the boilers were well blown down several times a day, and emptied once a month. The feeding in of a small amount of an organic acid to neutralise the alkali would also be of much service. By testing the boiler water in the manner previously described, the state of the boiler water could always be ascertained and the total solids kept down.

Soft waters, containing small quantities of a number of salts, are generally corrosive, and a water like the following should always be regarded with suspicion and watched accordingly.

Soft Corrosive Water.

Carbonate of lime	2·23
Sulphate of lime	2·82
Nitrate of magnesium	1·19
Chloride of magnesium	1·28
Nitrate of sodium	1·10
Sulphate of soda	·14
Choride of sodium	·45
Silica	·18
Organic matter	·31
	9·70

The corrosion is due to the chloride and nitrate of magnesium. Magnesium and calcium chlorides corrode iron very rapidly, owing to the fact that they are decomposed at high temperatures with the evolution of hydrochloric acid.

CORROSION IN MARINE BOILERS.

The causes of corrosion in marine boilers are complicated and many. First, there is the corrosion due to the chlorides either present in the sea water or produced by its evaporation. The water becomes concentrated by evaporation, as will be seen by a glance at the analysis given. This is water from a marine boiler using sea water as a make up. The ship was provided with an evaporator which was altogether unable to make good the loss caused by an abnormal leakage. This water is highly exciting. (It has already been shown what a complicated crystalline mass a boiler plate or tube actually is, and this crystalline mass by continued boiling in this highly charged water will gradually corrode.)

Marine Boiler Water. Analysis G.

Chloride of calcium	58·42
Chloride of magnesium	570·40
Chloride of sodium	5149·98
Sulphate of magnesium	468·67
Silica	29·61
	6277·08

Second, to further complicate matters, the oils used for the cylinders find their way into the boiler by way of the condensers. These oils, mineral hydrocarbons though they be, are oxidised by the high pressure steam now so general in marine engines, and are converted into oily organic acids. These acids attack the copper, lead, and zinc of the brass work, and the iron of the cylinders, and finally find their way into the boilers, charged with organic salts of these metals. A deposit taken from the cylinder of a marine engine using pure mineral oil and working at 160 lbs. pressure, contained 1·9 per cent. oily organic acid, 3·60 per cent. oxide of lead, 1·12 per cent. oxide of copper, ·17 per cent. oxide of zinc, and 52·66 per cent. oxide of iron.

Cylinder Deposit. Analysis H.

Uncombined oil	29·92
Combined oily acids	1·90
Carbonaceous matter	8·90
Oxide of lead	3·60
Oxide of copper	1·12
Oxide of iron	52·66
Oxide of zinc	·17
Lime	·13
Silica	1·19
	99·59

Cylinder Deposit. Undecomposed Oil removed by Ether.

Black carbonaceous matter	12·72
Combined oily acids	2·71
Oxide of lead	5·14
Oxide of copper	1·60
Oxide of iron	75·22
Oxide of zinc	·24
Lime	·19
Silica	1·70
	99·52

These oily organic acids form insoluble soaps with the magnesia and lime in the water, at the same time setting free their equivalent of hydrochloric acid to corrode the boiler, but fortunately there is always a considerable quantity of free magnesia floating about in a marine boiler using sea water, and this magnesia lays hold of these acids to form insoluble magnesia soaps, and therefore to a very large extent ameliorates the very active corrosion that would otherwise take place were their equivalents of hydrochloric acid set free.

It may be mentioned that the magnesia is produced by the reaction between the precipitated carbonate of lime and the chloride of magnesium in the boiler water, carbonate of magnesium and chloride of calcium being formed. The former by boiling loses its carbonic acid, becoming first magnesium hydrate, and finally, if the pressure is sufficiently high, magnesium oxide. Magnesia thus precipitated is a fine light powder that floats about in the boiler water, and does not form a scale. It is a singular fact that though sea water is rich in magnesium salts no magnesia finds its way into the scale of high-pressure boilers, which is composed of nearly pure sulphate of lime. The small percentages sometimes found are merely particles of the fine powder mechanically shut in by the crystallising sulphate of lime. This reaction also explains why the boiler water always contains chloride of calcium, for there is none in sea water.

These magnesia soaps are not harmless in themselves. They adhere to the plates, prevent the water from coming into contact with the iron, and are partially burnt on to the plates. Being very bad conductors of heat, the plates or tubes become red hot and collapse. These deposits, although not true causes of corrosion, are the very frequent means by which the iron becomes overheated, the result being the same, that is, the iron is unable to withstand the pressure and therefore collapses.

The composition of one of these deposits is shown in the following analyses :—

Oily Deposit. Marine Boiler.

Hydrated oxychloride of zinc	22·79
Oxide of lead	·47
Oxide of copper	·10
Oxide of iron	7·02
Magnesia	11·90
Silica	1·01
Combined oily acids	6·72
Uncombined oil	49·99
	100·00

Oily Deposit. Oil removed by Ether.

Hydrated oxychloride of zinc	45·58
Oxide of lead	·93
Oxide of copper	·20
Oxide of iron	14·05
Magnesia	23·80
Combined oily acids	13·45
Silica	2·02
	100·03

Oily Deposit. Marine Boiler.

Uncombined oil	51·14
Oxychloride of zinc and magnesia	21·82
Basic sulphate of zinc	4·98
Magnesia soap	14·71
Oxide of iron	4·50
Silica	·94
Sulphate of lime	2·16
	100·25

Oily Deposit. Oil removed by Ether.

Hydrated oxychloride of zinc and magnesia	44·66
Basic sulphate of zinc	10·19
Magnesia soap	30·12
Oxide of iron	9·20
Silica	1·92
Sulphate of lime	4·42
	100·51

Oily Deposit. Marine Boiler.

Magnesia soap	35·78
Basic sulphate of iron	10·25
Oxide of lead	·20
Oxide of copper	·30
Oxide of zinc	·41
Magnesic Hydrate	47·56
Magnesia	4·90
Moisture	·80
	100·20

(Note—No zinc was used in this boiler.]

These corrosive oily deposits are produced by comparatively good mineral oils of fairly high flash-points. With lower quality oils the amount of oily organic acids is so considerable that the iron is directly attacked and corroded, and the result is a hard black scale consisting mainly of oxide of iron.

Black Corrosion Scale produced by bad Oil.

Oxide of iron	72·26
Ferrous oxide	9·26
Ferrous carbonate	2·00
Sub-oxide of copper	·84
Magnesia	7·68
Sulphate of lime	1·75
Silica	·26
Oily organic acid	5·95
	100·00

No kind of oil should be allowed to go into a boiler under any circumstances if it can possibly be avoided. Of course with marine engines this may be impossible unless a means can be found for lubricating the cylinders with plumbago. The greatest discrimination should be shown in the selection of the oils, and only those should be used that show the least liability to oxidation. Many black mineral oils contain a partially oxidised body analogous to asphaltum, and this body shows a greater tendency to oxidation than the pure hydrocarbons. By using a properly prepared oil it is an easy matter to keep the cylinders free from deposit, and to prevent the formation of insoluble soaps in the boiler.

ACTION OF ZINC.

The copper and lead soaps from the cylinders are directly attacked by the iron, and copper and lead are precipitated on to the plate, thus setting up local galvanic currents to cause fresh corrosions, and one reason that zinc is effectual in preventing corrosion is the fact that it decomposes these soaps and precipitates the copper and lead upon itself instead of allowing them to deposit on the iron.

An analysis of the outer skin of a corroded slab of zinc taken from the same boiler that furnished steam to the cylinders containing the deposit before mentioned, shows the presence of 2 per cent. of metallic copper and 4½ per cent. of lead.

Besides this action, the zinc prevents the ordinary corrosion of the iron. Being a more active metal than iron it is dissolved before the iron, and therefore protects it in its immediate vicinity and by creating stronger electric currents between itself and the iron, destroys or neutralises the lesser local currents set up between the dissimilar particles of the boiler plates.

Zinc is soluble in sodium chloride *per se,* and this will account for the great consumption of zinc in marine boilers. The zinc will be dissolved by the sea water in the boiler whether the boiler is corroding or not, and the more impure the zinc the more rapidly will it waste. Cast zinc dissolves more rapidly than rolled zinc because it is generally more impure, and the slabs are often made by running down scrap zinc.

The chemical action whereby the zinc is corroded seems to be the formation of a basic sulphate and chloride of zinc. These salts are decomposed on continued boiling. Zinc oxide is deposited and a deposit of oxychloride and oxysulphate of zinc is formed. This action goes on until the zinc is perished, that is to say, until it is completely converted into zinc oxide, when it loses its efficiency and is of no further use as a protectant.

Analysis of Wasted Zinc Slab.

Oxychloride of zinc	3·89
Zinc hydrate	41·74
Zinc oxide	34·84
Lead	4·30
Copper	2·00
Sulphate of lime	4·40
Magnesia	8·64
Silica	·07
	99·88

Such then is as full an account of the various causes of corrosion as the limits of this paper will allow. Much more might be written on the subject but enough has been said to illustrate the various types of corrosion. Much stress has been laid upon boiler waters, that is upon the water contained in the boiler on evaporation, and it has been shown, that a water not actually corrosive, may become so on concentration, but the causes are so various that no one treatment can be proposed. The treatment for corrosive artesian well-waters must necessarily differ from that of an acid or a peaty water; and that the remedy is not always to be found in the application of soda ash has been conclusively proved.

Discussion.

The President asked the meeting to accord a very hearty vote of thanks to the reader of the paper. He was sure that they would all agree that the paper was one which would grace their 'Transactions,' and make the volume worth more than the subscription which was paid for membership with the society, and so compensate many members who were unable to attend our meetings. The paper would be found very useful for reference. He had himself had considerable experience in the control and management of boilers. But the paper had dwelt with a branch of the management of boilers into which his practice had not taken him, and therefore he felt very deeply indebted to Mr. Paul for the opportunity which he had afforded of looking into the subject from another point of view. They heard of all sorts of extraordinary things being done by men who were left in charge of boilers, and he was very sorry to say that very often engineers, who were generally supposed to be authorities on such subjects, instructed persons to do most ridiculous things to boilers under their charge. An instance of oversight or carelessness was given in the reference which was made by the author to the Huddersfield boiler. He saw around him many engineers who had had great experience with boilers, and he hoped that they would have a very interesting and full discussion. He was glad that a special reference had been made by Mr. Paul to the question of oils as affecting boilers. People were too apt to think that one kind of oil was almost as good as another. He considered that both as lubricants and as regards their effects on boilers oils required more attention than they received. He had seen most disastrous effects resulting from the action of oils introduced into boilers, more particularly of marine engines. They had passed through the condenser and completely crippled the boiler by affecting the furnace crown, although the other parts of the boiler had been perfectly sound. He would ask the meeting to signalise their appreciation of the paper in the usual hearty way.

Mr. Henry Adams said that he looked upon the paper as a valuable addition to the 'Transactions.' Having given some attention to chemistry in his earlier days he was prepared for some of the facts which the paper contained, but he must acknowledge that many of them were new to him, and he believed they would be new to other members. The old distinction between iron and steel being made dependent upon the amount of carbon present no longer held good; and recent investigation had shown that they must lay down new definitions for those materials. The figures given for the action of caustic soda upon iron were, he thought, open to various readings. It was evident that the percentage of loss on a very thin plate would greatly exceed that of a thick plate with the same total loss. He should like to ask whether they were pieces of boiler plate that were experimented upon, and whether one or both sides were subject to the action. He thought that all the circumstances should be stated to make the figures of practical use. The author had referred to iron when hydrogen was occluded, that being one of the results of the electrolysis of the water. This was a point which had not received much attention, and possibly the author could give some further information upon it. When the iron formed one pole, did hydrogen become occluded as the first effect, and then only the surplus come off in bubbles, or were the actions simultaneous? Did the occluded hydrogen escape later on, and if so, how? Did it remain long enough for a tensile test? Engineers generally liked to subject these things to the machine and test the result. Then, with reference to the sulphur, phosphorus and silicon, engineers very well knew that sulphur and phosphorus were objectionable, and that they acted in different ways upon iron. Sulphur rendered the iron brittle when it was hot. He understood the author to say that it rendered it soft and malleable. Phosphorus rendered the iron brittle when it was cold. If the author could give some information as to the reason of this difference, it would be very interesting and likely to be useful. He did not quite follow the author with regard to the lamination of the plates. He understood him to say that the decomposition of the carbonic oxide was an acid to the lamination. Generally speaking, lamination would be found to arise during the process of manufacture from the scale and dirt which were rolled in with the plates. Finally, as a marine engineer, he should like to know the name of the oil which could be used in the triple expansion engines without producing a tendency to pit the plates.

Mr. SCHÖNHEYDER said that he quite agreed with the President as to the great value of the paper, and the advantage which it would afford for reference hereafter. Possibly it would enable engineers to apply the proper remedy to feed water when they found that corrosion took place. But, on the other hand, he thought that it was best to apply at once to a good chemist for a complete analysis of the water, and for a distinct statement as to what was the right course to pursue with regard to the water. He should like Mr. Paul to state distinctly whether, in the case of the Huddersfield boiler explosion, where they were almost obliged to use bad water, it would have been possible to render the water less hurtful by the use of any kind of "medicine," if he might apply that term to the preparations which were used as remedies for bad water. For instance, would lime introduced into the boiler in such a case, have neutralised the effect of the water? With reference to the oil, which they were almost obliged to use in engines, he would ask the same question as the last speaker asked—viz., Was it possible to find any oil which could be used at the high temperatures at which they now worked, and which would not decompose and not cause damage?

Mr. JOSEPH BERNAYS agreed with what had been previously said as to the high value of the paper. With regard to the use of "medicine" for the improvement of boiler water, he might state that he once had to provide some boilers in a factory which derived its water from a kind of artesian well passing through a thick stratum of peat. The water was wonderfully sparkling and fine, but he thought it best to take the opinion of a chemist as to whether it could be safely used for the boiler. He asked a question somewhat similar to that which Mr. Schönheyder had just asked. It was not exactly what medicine they should use, but whether the water was suitable for the intended purpose, or what should be done if it be found unsuitable. The reply of the late Dr. Vœlcker, whose opinion had been asked, was that the only thing they could do was to throw it away, and try to get water from the water company. That was the remedy which Dr. Vœlcker proposed, and which was ultimately adopted. He (Mr. Bernays) was acquainted with another case which rather puzzled him and those connected with the matter, and it puzzled them so much that they had to give it up. He provided some locomotives for a mine with which he was connected. Of six of the locomotives supplied four answered in every way, but two of the engines seemed to be constantly in trouble; the boilers began to leak, and when the tubes were taken out the insides of the boilers were found to be fearfully pitted. They could not find out where the difficulty arose. All the engines were apparently fed with the same water, and were even driven by the same drivers, and had about the same service to perform. Two of the boiler shells were very considerably pitted along the water line, so much so that in the end they had to be abandoned, and replaced by new shells. All these boilers were made from the same brand of iron manufactured by one of the best firms for Yorkshire iron. He made every inquiry, but he could find no difference, either in the treatment or in the water, between the engines which gave the trouble and the others; but still the difference in behaviour was an established fact. Perhaps Mr. Paul might be able to give them an idea of how the difference was to be accounted for.

Mr. W. MAXWELL WILLIAMS said that he was an old boiler inspector, and he had been very much interested in the paper. There were one or two simple tests which might be used for ascertaining impurities in ordinary water. For instance, quicksilver would detect the presence of sulphur, and iron salts could be discovered by ferro-cyanide of potassium. Easy tests of this kind would be very useful to boiler inspectors. One object of boiler-makers naturally was to get a very good pure metal, because it was more easily worked and more reliable; but he was perfectly certain that, although the purer metal might be very satisfactory to the boiler-makers, it was found by owners, to whom the life of the boiler was the important question, that the purer the metal the more liable it was to be pitted. That, at least, was his experience. Another curious thing which he had found, and especially in marine boilers, was that one plate would be badly pitted, while an adjoining plate, but of another quality or brand, at the same level with regard to the water line, would not be affected at all, the higher-class plate being the one to suffer. He thought that the author was perfectly right about the copper patch having something to do with the pitting in the Huddersfield boiler. It had struck him that, as copper steam-pipes were being given up on account of the high pressure now employed, it would be a very good thing if iron or steel pipes were also used for the feed. He was certain that feed water, especially hot condensed feed water, which passed through copper feed pipes to the boiler, affected the copper. He once instructed the chief engineer of a boat he was engineer-superintendent of to hang a zinc plate about 1¼ inch thick in front the main feed water entrance, and in a few days a hole was eaten right through it. This was not astonishing, as the feed pipes were copper. He used cast zinc at that time, but he never used it now. He found that rolled zinc answered better, and, though costing more in the first instance, was cheaper in the end. One objection to the cast zinc was that it flaked and fell down between the tubes, and on to the furnace crowns. Rolled zinc was not liable to do that. He agreed with the author with regard to the use of soda: but that which is known as common, or washing soda, is not so open to objection as caustic soda.

Mr. A. H. Allen said that he must express his obligation to the Society for inviting him to attend the meeting and take part in the discussion. He had practised for many years as a consulting chemist in Sheffield, and therefore took a great interest in everything relating to the chemistry of iron and steel. As he had to analyse hundreds of samples of boiler water, and had also been largely concerned in the analyses of oils, there were various points in the paper which naturally interested him. He congratulated the author in having brought before the Society such an enormous number of facts, and on the way in which those facts had been marshalled by him. That he, Mr. Allen, should agree absolutely with everything which had been stated in the course of a long paper of this kind was not to be expected, but he was able to endorse most cordially the larger part of what Mr. Paul had stated. The paper had brought before them, in a very prominent and convincing way, the evils which might be brought about by putting too much alkali in the water, and which might also be done by oil and several other things which were commonly overlooked or which did not receive sufficient attention. In the Blackmoorfoot water, at Huddersfield, they had mineral acids to deal with. In the Sheffield water they had organic acids which, he had no doubt, were derived from peat, and which certainly corroded iron and lead. A few years since he could not draw a drop of water from the service-pipe which did not contain the dangerous proportion of half a grain of lead per gallon. But this evil had been cured absolutely by the judicious employment of chalk. This fact proved first that the acid was the cause of the evil, and, secondly, that they knew how to deal with it. He should like to know how Mr. Paul estimated the proportion of basic sulphate of iron when ferric oxide was simultaneously present. It was a little difficult to make out the way in which these substances existed; and he would appeal to Mr. Paul, on behalf of chemists generally, to state, when his paper came to be printed, not only the form in which he believed the iron to exist, but also the quantity calculated out in the form of iron oxide. The ordinary deposit of the Huddersfield water contained about 1½ per cent. of silica, whereas, when there was a copper patch on the boiler, there was 11½ per cent. He did not understand how this happened. With regard to the artesian well water, he did not quite understand why Mr. Paul expressed the iron as bicarbonate and the soda as bicarbonate, but expressed the lime simply as neutral carbonates. He hoped that Mr. Paul would furnish them with another table in which they would be able to see the quantity of iron and soda apart from the carbonic acid. He did not understand the action by which, as the author supposed, caustic soda was formed. It seemed to be a very serious matter that it should be there. Mr. Paul did not refer, at any rate in detail, to the injurious effects of chloride of magnesium in water. This was a very important matter, as, whenever they had magnesium salts together with chlorides, there was potentially chloride of magnesium present. This constituent was objectionable because, on evaporating the water, it split into hydrochloric acid and magnesia, and the hydrochloric acid corroded the boilers. There was only one exception: chloride of magnesium and chloride of sodium both existed in sea water, and sea water contained far more chloride of magnesium than many fresh waters, and yet it did not cause the peculiar corrosion, especially at the water line, due to chloride of magnesium. This was probably in consequence of its association with a large quantity of chloride of sodium, by which a double chloride of sodium and magnesium was formed, which would stand evaporation to dryness without decomposition. Hence it appeared that chloride of magnesium was not prejudicial under all circumstances, but would be so unless there was a sufficient quantity of chloride of sodium to convert it into a stable double compound. He was very much struck with what Mr. Paul had said on the subject of oils. He regarded it as true scientific practice that that animal and vegetable oils were being replaced so generally in high-pressure cylinders by pure mineral oils. These were not liable to that saponification by superheated steam which all animal and vegetable oils underwent. In looking for acids of all kinds in the analyses of mineral oils he, Mr. Allen, could, as a rule, only find minute traces. He wished to ask Mr. Paul how he ascertained the amount and how to express it. Something had been said about the use of " medicine " to cure the formation of incrustations in boilers. He preferred to call it "physic"; and he believed that the direction to " Throw physic to the dogs" should be applied to the greater number of boiler physics. There was no doubt that, in a large number of instances, there was a tendency to acidity in the boiler water, and this could only be cured by means of alkali judiciously used. The difficulty which he met with was to get his clients to use enough. They expected to be able to prevent the formation of the boiler deposit by using a mere homœopathic dose of soda ash. The proportion to be used must vary with every boiler water. The boiler-composition companies were prepared to state how much of the composition ought to be used; and some of them even dispensed with the ceremony of analysing the water, without which, however, the composition might do more harm than good. He hoped to see the paper printed in due course, and had listened to it with great interest, and received much information from it.

Mr. Chris. Anderson said that he had had the same experience as had been described by some of the former speakers with regard to corrosion, but the subject was a chemical one and he was not prepared to discuss it.

Mr. Shirley-Price said that he could confirm the remarks which had been made about some of the water. Fifteen or twenty years ago he went to some ironworks near Peniston, and he found that the duration of a Low Moor boiler was frequently

18 months. At last the blast furnace at these works had to be given up, one of the principal reasons being that the owners could not afford new boilers so frequently. The water originally came from the peat moss. The action of the water on the boiler was very peculiar. It could hardly be called incrustation as the effect which it produced resembled the appearance which would be made on a piece of dough if a schoolboy's "alley" or large marble were dropped upon it, or if an impression were made with the knuckles of a person's hand. These marks were sometimes 6 inches or more apart. The effect was not lamination or incrustation, but "pitting." This went on year after year, and the boiler bill was ruinous. He remembered that in Lancashire there were was great faith among the old millwrights in oak bark. Not being a chemist, he would ask Mr. Paul what was the action of oak bark upon the water? The remedy was an old-fashioned one, but whether it was a good one or not he could not say.

M. W. JENKINSON said that it had been stated that the corrosion of the Huddersfield boiler was owing in a measure to the copper patch. Two pieces of broken boiler plates had been passed round the room. One of these was taken from the Huddersfield boiler, and the other was from a hot-water boiler. As the corrosion was similar on both specimens, he should like to know whether there was any copper patch in connection with the second specimen. Mr. Paul had given them to understand that pitting was worse than general corrosion. He, Mr. Jenkinson, held just the opposite. For instance, in the Huddersfield boiler the plate was generally corroded. Had it been only pitted here and there, but more deeply than it was, possibly one place might have relieved itself, but there would have been no explosion; but the plate was so generally corroded all over the circumference of the fire-box that it was only a matter of time, and the boiler was certain to explode. The importance of the paper was seen by the returns of the Board of Trade, which showed that the great majority of explosions occurred in consequence of corrosion. In the year 1880 there were 37 explosions, 14 of which were caused by corrosion. In that year there were 71 deaths, 55 of which were caused by explosion due to corrosion. If they could only get over corrosion they would do away with many of the more serious explosions in steam boilers.

In the year 1887, which was an exceptionally dry season, very serious and exceptional instances of corrosion were found in different parts of the country. In some parts of Lancashire, where the boilers were fed from corrosive waters, some of the boilers were almost ruined in the course of that year. Boilers which were almost new had to have new furnaces put in during that year. With regard to the quality of boiler plates there was no doubt that corrosion took place more rapidly on better class iron than on inferior. He remembered a case in the Midlands where a boiler that had a Loor Moor furnace, which had only been in for nine months, was so seriously corroded in that time, that it had to be renewed. Although the furnace was of Low Moor iron, the other plates were of a commoner kind; but it was the furnace plates which were corroded, and not those made of the commoner kind, the latter being untouched by corrosion; and he had known other cases of a similar nature. In many cases the corrosion could be easily stopped, and he thought that that was a practical point for them to-night. Some years ago he knew a case in which a group of boilers had corroded very rapidly. Samples of the water were sent for analysis to a professor of chemistry in the North of England, who advised a certain chemical treatment, and when this advice had been followed for three months, an examination was made, and the corrosion was found to be considerably abated, although it was still going on slightly. At the end of six months it had entirely ceased, and he believed that there had been no corrosion since. Another thing which engineers ought to take notice of was the great changes which took place from time to time in water in the same locality. He did not think that it was possible to stop corrosion in all cases, but he believed that it might be stopped in the majority of cases if only specialists were consulted. He did not believe in an elixir which would cure every complaint, but he believed that there were makers of compounds who, by analysing the water with which boilers were fed, could give a suitable remedy.

Mr. A. Rigg said that he should like to ask Mr. Paul a question about one of the specimens of plate which had been shown to the meeting. The plate generally seemed in very good condition, except where the light could be seen through some places. Was it a sample from an actual boiler; and if so from what exact part had it been taken? It was very remarkable that corrosion had only taken place in some parts.

Mr. P. F. Nursey said that it was about 25 years since he began to think, talk, read, and write about boiler corrosion, but until to-night he had never learned so much about the cause of it. Their thanks were certainly due to Mr. Paul for having thrown so much light upon the subject. There was no doubt that the cause of corrosion had been hitherto shrouded very largely in mystery. There were in the market a large number of nostrums for bad waters which had been used indiscriminately, and fatal results had thus been brought about in some instances. He believed it was impossible to find the precise remedy required for any given water unless the water was properly analysed, and the remedy defined by a competent water analyst. With regard to the effect of lubricating oils, he had had some little experience of their use, but rather in an inverse direction if he might so express himself, that is to say, it was the injecting oil into the boiler. About 1874 he was interested in a very interesting invention which was patented by Mr. Major, an engineer in the Danish Royal Navy, for preventing priming in boilers. The oiling apparatus was fitted up in connection with the 50 horse-power boiler of a cargo boat belonging to the Brighton Railway Company running from Littlehampton. Highly rectified petroleum was used, and about half a pint was passed into the boiler with the feed water on the vessel leaving the port, and half a pint more when she was about half way on her 12 hours' run. This treatment entirely cured the priming, and more than that, it prevented incrustation and largely aided lubrication, the petroleum being carried through the cylinder by the steam. Beyond this it had a very good effect in preventing incrustation in the boiler; as occasional examination showed that the scale was either thrown down or was very easily removed from the boiler plates and tubes. The apparatus was also used with success in two or three steamers running on the Tyne. He went to the Admiralty with the view of introducing it into the Royal Navy, when he found they were using petroleum for the same purpose but in a different way. They simply injected it at intervals against the boiler pressure. These facts afforded instances of petroleum being applied with beneficial results to the boiler, both as regards incrustation and priming, and also not without useful results in respect of cylinder lubrication.

Mr. J. **Rosenthal** said that the remarks which Mr. Nursey had just made with regard to the use of oil in a boiler were certainly startling to him, because all the experience which he had had tended to show him that oil was bad anywhere. With regard to the remarks of Mr. Price, it seemed to him, Mr. Rosenthal, that, if the owners of the iron works in question had consulted an engineer, a remedy might have been suggested. They might have fed the boiler with water from surface condensers.

Mr. F. E. **Duckham** said enquiry had been made as to the best "medicine" to counteract the corrosive action of water in boilers. He did not believe in medicines in boilers, if not chemically correct for the particular case they did more harm than good. He had found the internal application of a thin coat of tar safer and more effective than any chemical mixture.

He had so treated a range of Lancashire boilers for about 20 years; there had been no corrosion and an almost entire absence of the scale and chipping previously necessary. As to the removal of impurities from boilers, the Millwall Dock Company's dredger had two marine boilers and compound surface condensing main engines, but as there were three active deck winches exhausting steam overboard, a lot of feed water was required to make up, and this water being drawn from the dock, where the mud was being stirred up by dredging operations, it was particularly dirty and the boilers got very foul. Three months ago he fitted a Hotchkiss boiler cleaner to one of the boilers, leaving the other as it had been. This appliance so trapped the impurities which were in the water and enabled them to be removed, that upon the boilers being opened up a fortnight ago, whereas the unfitted boiler had its usual nine or ten buckets of deposit, that fitted with the cleaner had one and a-half bucket only. He thought the complaint of grease being found in boilers would disappear if proper lubricators were employed, i.e., such as would regularly supply just so much lubrication as the engine required.

Mr. R. H. Harland said that his experience showed that mineral oil which was absolutely pure, and which had a high specific gravity and would stand a good cold test, had no action on the iron plates or any part of the boiler. He should imagine that the cylinder oil which produced the deposit in analysis H. was probably impure, and contained a small amount of some vegetable or animal oil mixed with it. Chemists knew that when mineral oil was prepared in the most careful way by repeated distillation, it was exceedingly unlikely that anything of an acid nature could be generated from it, even at the temperature of steam in a high-pressure boiler. He felt sure that the quality and the nature and proportion of the impurities in the iron had more to do with corrosive action than was generally thought, especially when soda ash is used. He had two instances in his mind at that moment; one was a case in which the water had been treated for some years with eight or nine pounds of soda ash to the thousand gallons, with the most satisfactory results. No pitting or corrosion of any kind could be detected in the boiler or fittings. In the other instance the soda ash had been used to the extent of only half-a-pound in the thousand gallons, and its use had to be discontinued on account of pitting in the boiler and corrosion and consequent leakage of the cocks and fittings.

The President, in calling upon the author to reply to the discussion, asked him to be good enough to embody in the form of writing that part of his reply which related to Mr. Allen's remarks. In that way Mr. Paul could reply with more justice both to himself and to the meeting.

Mr. Paul, in reply, said that with the permission of the chairman he would reply to one or two of Mr. Allen's remarks at once. Sand and dirt collected under the flanges and so increased the silica in the deposit taken from that part. A large experience of boiler scales shows that there is a very great difference not only in the scales deposited by the same water, but also in the scales taken from different parts of the same boiler. Mr. Allen had asked about the presence of caustic soda in the boiler water. In analysing boiler waters containing carbonate of soda, he (Mr. Paul) had very often found caustic soda in addition to the carbonate, and this was more especially the case when the boiler was worked at high pressure. Up to the present he had been unable to account for it unless judging from analogy it might be assumed that carbonate of soda, like carbonate of magnesia, parted with its carbonic acid on prolonged boiling under pressure in a saline solution. However, if this were the case it might also be expected that carbonate of lime would act in the same way, but he had not yet come across free lime in any boiler scale, though he had seen it returned as such by another chemist in a sample of burnt scale.

No doubt chloride of sodium to a very large extent increased the stability of chloride of magnesium, but as had been explained in the paper, there was another re-action in which chloride of magnesium takes part, that is with carbonate of lime, yielding magnesium carbonate and chloride of calcium, a salt much more stable, and therefore less corrosive than chloride of magnesium; while to a very large extent the deposited magnesia found floating in the water preserved the boiler from acid corrosion.

The subject of boiler medicine, mentioned by several speakers, was a very important one, as in most cases it was impossible to treat the water elsewhere than in the boiler. But before the physic can be prepared the water must be analysed and thoroughly analysed. No analysis merely giving the amounts of free and albuminoid ammonias, the hardness, chlorine and total solids, is of any value for the purpose. The ordinary analysis given by most chemists is not enough, a full and arranged analysis must be made before the action of heat on the water can be understood. The hardness test is of no practical value except for soap-destroying power, and the hardness given by this test has seldom, if ever any close correspondence with the actual amount of lime and magnesia salts in the water, and further the results obtained by evaporating the water for half an hour in an open vessel under ordinary atmospheric pressure, bears very little relation to the results obtained by the constant evaporation in an iron vessel at perhaps 150 to 200 lbs. pressure. For boiler purposes one did not require to know the small amounts of organic ammonias, nor the oxygen consumed, &c., &c., to which special prominence was given in an ordinary analysis of potable waters. One required the actual amounts of the mineral constituents of the water, and to know how they are combined. Hence the suggestion of Mr. Maxwell Williams that easy tests should be given to the engineer was in this case impracticable, and would be certain to be misleading. The analysis should be thoroughly done, or else left alone. When the constituents of the water were known experienced chemists could prepare the proper remedy. There is no patent medicine for boilers, and no specific that is to cure all waters should on any account be put into a boiler. The question of quantity just touched upon by Mr. Allen was one of the first importance, and was perhaps the *crux* of *the* whole question. Steam users expect that a few pints of a boiler preparation is to do all the work required. A 30 feet by 6 feet Lancashire boiler evaporating any of the London companies' waters and working at its full capacity requires 10 gallons per week of the strongest preparation that can conveniently be made, to effectually deal with the impurities contained in the water evaporated during that time. By analysing the water a method of treatment could be worked out for Huddersfield or any other kind of water. Any water could be dwelt with, and it was entirely a question of cost even if the water had to be distilled. In some cases the cost of treatment rendered the water too dear for use, and he (Mr. Paul) had often been in the predicament mentioned by Mr. Bernays, of having to advise the water to be thrown away, and that of the water company's or other convenient supply to be substituted for it.

The account of the manufacture of boiler plates given in the paper clearly pointed to an answer to Mr. Bernay's other enquiry about the corrosion in two out of six similar locomotives all worked under precisely similar conditions. It had been pointed out that one plate could not be made chemically homogeneous. How much more likely then, that different plates, although made from the same iron, should show different chemical activities towards the same corroding agents. If this were not so, boilers would suffer from general corrosion and there would be no pitting.

In reply to Mr. Duckham, he could only say he was not in possession of sufficient information about the waters and about the state of the boilers to offer any decided opinion as to the effect of tarring the inside of a boiler. He did not like to draw a general conclusion from one or two isolated cases. It, the tarring, was a thing he would not like to do. Many questionable things might be done fora long time without causing much damage, for instance a man might sit on a safety valve with impunity for a long time without bringing about any disaster. At the same time it was a thing no one thought was right, and no one would do himself. The Hotchkiss Separator had only done what a settling tank or a filter would have done equally well. It had not acted as a preventer of corrosion but merely as a mud or sand-stopping tank.

Mr. Jenkinson had pointed out cases in which the purer iron was more rapidly corroded than the commoner and less pure iron. This he could quite understand, and had pointed out this fact in the paper. The solution of the difficulty of getting boiler plates to better withstand the corroding influences to which they are subjected was found, not in a purer form of iron, but in a more homogeneous mixture of pure iron with minute quantities of iron alloys, intimately associated by a scientific thermal treatment. He (Mr. Paul) could corroborate what Mr. Jenkinson had said about the variable nature of natural waters.

Mr. Shirley Price had asked a question about the effect of oak bark. Oak bark contained a considerable quantity of free tannic acid ; this acid decomposes carbonate of lime and forms an insoluble tannate of lime which does not bake into a scale, and can be removed by the blow-off cock. With certain alkaline waters and in careful hands oak bark may be used with success. But extreme care must be used, as tannic acid attacks iron and removes scale by corroding the iron beneath it. So long as the water in the boiler is kept alkaline, it is quite safe, but if the water be not kept alkaline the boiler will certainly be corroded.

The paper had been written for engineers rather than for chemists. He had endeavoured to put the matter as clearly as possible before those for whom it had been written. They knew that when water containing bi-carbonate of lime was boiled, a portion of the carbonic acid went off in the form of gas and carbonate of lime was left behind. He had therefore returned his results as carbonate of lime to show exactly the amount of the substance which was going to form the incrustation. In his own copy of the analysis he had got it returned as bi-carbonate of lime, but had put it in the present form because he thought it would be more clear to a meeting of engineers. A great number of the analyses would have been differently stated if he had been writing for a meeting of chemists. He should have stated the exact amounts of ferric oxide, the amounts of water, the amounts of lime, and let chemists calculate it out for themselves; but for engineers he thought it best to arrange the materials, so that they could see at a glance what the various bodies really were. Mr. Harland and other speakers had alluded to the question of oils. He, Mr. Paul, found that certain mineral oils when heated in a current of high-pressure steam developed an acid body. It was all very well to say that the oils were not pure mineral oils, but he knew that they were, for he had tested them. He necessarily took the precaution of testing them before starting. The oils which yielded the deposits mentioned in the paper were pure mineral oils. There was a certain amount of a black asphaltum-like body, but no animal or vegetable oils or fats. Unfortunately he could not give Mr. Adams the figures for which he asked, but certain notes to the paper, which he had not read, would no doubt afford some of the information desired. As to lamination he agreed with Mr. Adams that in most cases the lamination existed in the boiler plate before it was placed in position in the boiler, but he was also of opinion that sometimes the lamination was caused by the action of the fuel. Owing to the intense heat, especially with an encrusted plate, carbon was absorbed, and a more or less impure layer of cast iron formed which, having a different appearance, was put down to original lamination or some fault in the manufacture. No doubt in a great many cases there might have been an original fault but the process mentioned was sometimes the causes of the laminate appearance. The tendency now-a-days was towards a higher working pressure in steam boilers, and to-day 160 to 180 lbs. is not an uncommon pressure. It was most economical and allowed triple or even quadruple expansion. Such being the tendency amongst engineers, boiler-makers must, and do, keep pace with the times, and have produced boiler plates that will work at this pressure. But what was the use of the boiler-makers turning out these plates if the boiler users cannot keep them in working condition? Every pound increase in the working pressure was an increase in the temperature of the boiler plates and was a step nearer the point where iron rapidly decomposed pure water; hence the higher the pressure the more carefully must boilers be watched and worked, and the more full should be the information placed in the hands of the engineer. This had been his aim in writing the paper, and if the paper had contributed anything to the engineer that would enable him to keep his boilers in a more satisfactory working state and prolong their lifetime, he would feel amply repaid.

Appended are the figures asked for by Mr. Allen :—

Deposit from Huddersfield Water. Data.

Ferric oxide	59·04
Lime	15 84
Sulphuric acid	23·39
Silica	1·48
Magnesia (diff.)	·25
	100·00

Deposit from Copper-patched Boiler. Data.

Ferric oxide	55·92
Oxide of copper	12·52
Lime	5·06
Magnesia	·80
Sulphuric acid	8·76
Silica	11·56
Loss on ignition	5·40
	100·02

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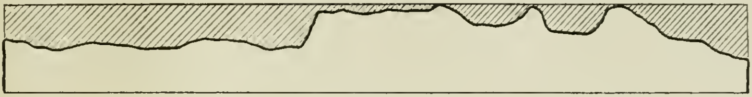

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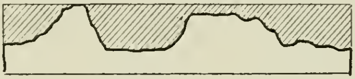

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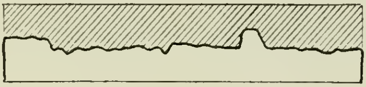
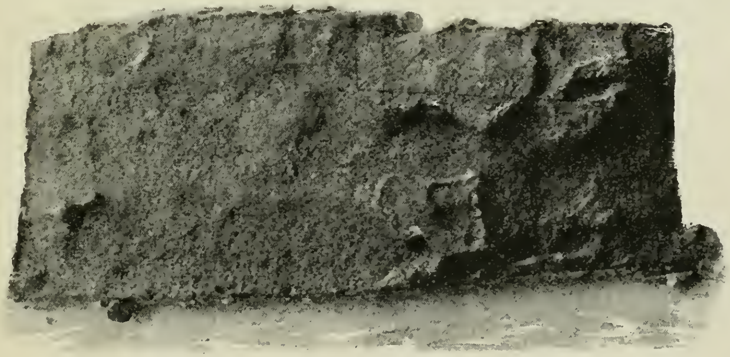


The shaded parts shew where the iron has been removed by corrosion.



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W. N. COLAM, President, in the Chair.

THE DRAINAGE OF TOWN HOUSES.

By George Maxwell Lawford.

In the great majority of town houses the drains are necessarily laid under the house itself, and it is with special reference to these cases that the present paper has been compiled, starting on the assumption that the house has been built in a substantial manner on good foundations, and that the necessary precautions have been taken to ensure proper ventilation and to exclude the damp. Mention may be made of the "heroes of a by-gone age," such as brick drains, unventilated syphon traps, bell-traps, pan closets and their attendant satellites D-traps, cisterns with standing trumpet wastes in direct connection with the drain and many other kindred abominations which are even now to be met with daily, but as their various defects are so well known, further reference is unnecessary, their sun having long since set.

The objects to be attained in carrying out a perfect system of house drainage are as follows :—

1. The primary disconnection of the house-drain from the main sewer.

2. The thorough ventilation of the entire system.

3. The secondary disconnection of the rain and waste water pipes from the house-drain.

4. The immediate and absolute removal of all matters discharged into the drain from any source whatever, and lastly,

5. The construction of the entire system in such a manner as to prevent foul gases or currents of polluted air from entering the house, and of such materials, as to preclude the possibility of the leakage or escape of both gases and liquids.

An explanation of the words "disconnection" and "trap" is necessary, as although they are now terms of every-day use, they very frequently are completely misunderstood.

By "disconnection" is meant a severance of the direct line of communication in a pipe or drain, by means of which, without causing any actual interruption in the flow of liquid in the pipe, fresh air is admitted to that portion on the upper side of the break, while the foul air on the lower side is "intercepted" or excluded by a dip formed in the pipe in such a manner as to retain a constant volume of water which prevents the passage of foul air through it.

This dip or bend in the pipe is termed a "trap," and the water standing in it is said to "seal" the trap, while the phrase "a water-seal of so many inches" means the vertical dimension between the standing level of the water and the lowest point of the soffit at the dip.

Examples of horizontal and vertical disconnection are shown in Figs. 1 and 2, the arrows indicating the admission and passage of fresh air.

The primary disconnection of the house-drain from the main sewer is effected by means of a ventilated intercepting trap which, under normal conditions, prevents the ingress to the house-drain of gases generated in the main sewer. The trap should be provided with an arm to give access to that portion of the drain between it and the main sewer in the event of obstruction, the arm being closed by an air-tight movable stopper. This trap is usually placed in a manhole for convenience of access, the drain terminating in an open channel-pipe running into the trap. The manhole should have an air-tight iron cover, and be ventilated by means of a short length of pipe carried up to a point a little above the ground level and ending with an open vertical grating, through which fresh air is admitted to the manhole and thence to the drain, thus completing the disconnection.

It has been proved beyond dispute that the water in an unventilated trap, unless frequently changed, will absorb gases to such an extent as to pass them through in a comparatively short space of time, and again in times of heavy thunderstorms, when the sewers are surcharged, gases are forced through, thereby showing the necessity for disconnection; and it is now admitted by all competent authorities that trapping alone is not a sufficient safeguard against sewer gases. An illustration of a disconnecting manhole showing a trap with access arm as described and an air inlet shaft is shown in Fig. 3, the cross section, Fig. 4, showing the channel-pipe.

The second object, viz., the thorough ventilation of the entire system, also requires a word of explanation, as numberless cases of so-called drain ventilation are to be seen daily, in which a soil pipe or shaft is carried up to the top of a house without any provision being made for the admission of fresh air.

Ventilation, as applied to drains, denotes the continuous passage or circulation of a current of fresh air through the horizontal and vertical pipes forming the system, by means of which gases which have either been generated in the drain or absorbed into it, are diluted to such an extent as to render them inoffensive, and in order to accomplish and maintain this condition *there must be an inlet as well as an outlet.* The pipe or shaft, described in connection with the manhole, serves to admit fresh air to the entire system and acts as a down-cast shaft, the current of air thus admitted serving to carry off at once and thoroughly dilute any gases in the drain. It then passes along to the highest point or head of the horizontal drain, where there should be an up-cast shaft having an air-tight connection with the drain, and carried up, with as few bends as possible, high enough to be clear of all windows and roofs in the immediate vicinity.

It frequently happens, more often than not, that this up-cast shaft is the soil-pipe, which, in the case of town houses, is usually at the back and is carried into a small inspection chamber placed in a back or central area by means of which access can be obtained to the drain passing under the main body of the house as shown in Fig. 5, which is a section giving the relative positions of the disconnecting and inspection manholes and of the down-cast and up-cast shafts.

Where this arrangement is adopted, *i.e.* where the up-cast shaft is the soil-pipe, it is the general impression that whenever a closet is discharged, the pipe is filled momentarily with a body of water which, plunging down with a piston-like action, forces out the air in the drain through the fresh air inlet, and creates for the time being a reverse current in the down-cast shaft. This current being more or less foul, according to circumstances, it has been considered advisable, almost universally, to check it from issuing out of the inlet by means of a valve or flap of mica hung in a suitable box so as to open inwards only, and to close automatically with an up current. The author is of opinion that this is unnecessary, and that a plain grating, sufficient to keep the inlet free from obstruction, will answer all practical purposes, the reverse current being created, if at all, for a second or two only, as the pressure caused by the falling body of water in the soil-pipe is very considerably diminished, if not entirely expended, in the horizontal drain before it reaches the inlet, the horizontal drain being as a rule larger than the soil-pipe, while the difference in form between a given volume of water falling vertically through a cylinder and an equal volume running through a similar cylinder laid at a uniform inclination, is too well known to need further comment.

As a rule, in town houses, it is possible to arrange the drain in such a way that the principal soil-pipe forming the up-cast shaft enters the drain at its highest point, but in cases where a branch drain, or the main drain itself, is carried to any considerable length beyond the soil-pipe, a subsidiary ventilating shaft should be connected to the extreme end or head of the drain, which would otherwise become an unventilated "dead-end."

The use of cowls for strengthening the current in up-cast shafts and for preventing blow-down, has been a frequent subject of debate, but the author does not consider them to be necessary adjuncts, as in addition to the strong possibility of obstruction, the result of a series of tests carried out by a committee of the Sanitary Institute, consisting of Captain (now Sir Douglas) Galton, the late Mr. William Eassie, and Mr. Rogers Field, at the Royal Observatory, Kew, in 1878, showed that the only use of cowls was to keep out rain; the top of the shaft should, however, be protected against obstruction by a domical wire grating or cone.

The question of trap ventilation is one requiring very careful attention, as when two or more closets or other appliances discharge into one vertical pipe, the traps of the lower appliances will be unsealed owing to the syphonage produced by the rapid descent of a body of water from a higher level, unless air is admitted independently in front of the traps of the lower appliances. A ventilating pipe should therefore be taken off the the lowest trap of the tier, as shown in Fig. 6, and carried vertically upwards to the same height as the soil-pipe, branches being taken off it and connected to the traps of all the appliances on the tier. This pipe really serves the double purpose of preventing syphonage and carrying off any effluvia from the standing water in the traps by maintaining constant air circulation; the lower end should be continued to the inspection chamber, in order to be in connection with the air inlet shaft.

The remarks in the last paragraph will apply equally to a horizontal tier of traps, such as a range of lavatory basins, each trap being ventilated by a pipe branched into a continuous ventilating shaft which should be carried up vertically outside the building. An arrangement of this kind, as shown in Fig. 7, in addition to preventing syphonage in the traps, will rectify another matter which is frequently neglected, viz., the ventilation of the dead ends of waste pipes from baths and lavatories. These appliances should always be placed against an external wall in order to reduce as much as possible the length of lead pipe connecting the traps of the appliances to the external vertical stack pipe. The smell from lead pipes lined with soapy deposit is most objectionable, and those who have had practical experience on this particular point will doubtless agree with the author's views, viz., that such waste pipes should, without exception, be trapped, and that where a considerable length of internal waste pipe is absolutely necessary, it should invariably be ventilated.

The secondary disconnection of the rain and waste water-pipes from the house-drain is effected by means of gullies, which are virtually small intercepting traps, and which are placed at the heads of branch drains in order to shut off from the vertical pipes any gases generated in the main house-drain. All waste and rain-water pipes should terminate with open ends at these gullies, which are of various forms, those in general use being shown in Figs. 8 to 11.

Speaking broadly gullies may be divided into two classes, viz., those which receive the discharge above, and those which receive it below the grating, the point of discharge being in all cases above the level of the standing water.

Referring to the diagrams, Fig. 8 is the gully in general use where the discharge takes place above the grating; Fig. 9 is used for the disconnection below the grating of small pipes, such as those from sinks and lavatories; Fig. 10 is used for the disconnection below the grating of 3-inch and 4-inch vertical rain-water and waste pipes, and Fig. 11 has a back inlet for disconnecting a length of horizontal drain.

The advantage claimed for the three latter forms is that the grating is not likely to be obstructed, such matters as leaves, matted hair, soap and grease, passing direct into the gully, whereas if the form shown in Fig. 8 were used there might be frequent obstructions.

The author contends that the form of gully used should be entirely subservient to the arrangement of the vertical pipes. Owing to the frequent adoption of double disconnection for waste pipes by means of hopper heads on the stack pipes, a practice to which he is entirely opposed, it follows that where any one of the three latter forms is used, as shown in Fig. 12, any effluvia from the water in the gully would naturally be drawn up the vertical pipe and be liberated at the hopper head. More often than not, this is found in close proximity to a window, whereas if the arrangement shown in Fig. 13 were adopted, the gases would pass at once into the open air where they would be harmless.

Fig. 14 shows the manner which the author considers to be the only proper one of dealing with these waste pipes, viz., treating the vertical pipe as a soil-pipe, but disconnected at its foot, as by this method the unnecessary double disconnection is avoided, and all chance of effluvia from the ends of the smaller waste pipes re-entering the house by the windows is rendered impossible, and as the vertical pipe is carried upwards and ventilated like a soil-pipe, it is perfectly immaterial which form of gully is placed at its foot.

The immediate and absolute removal of all matters discharged into the drain, whether excrementitious or otherwise, is a point which seems to have been overlooked entirely in the past, and is even in these modern days treated only too frequently with but scant consideration.

Two of the three essential factors which facilitate the prompt removal from the house and the rapid delivery into the main sewer of the various waste and refuse matters, which, whether liquid or solid, find their way from one source or another into the system, are the size and inclination of the house-drain.

The third factor is the motive power by which these matters are removed, and it is hardly necessary to point out how vitally important it is, not only to provide for, but also to secure, the proper and efficient use of a liberal supply of pure water.

With regard to the two first-mentioned factors, it is a matter of every-day occurrence to find a 9-inch or even a 12-inch pipe-drain under a town house, and the author has in occasional instances met with 18-inch brick barrel and even rectangular drains. A 9-inch pipe when laid at an ordinary gradient is sufficient for the removal of the sewage proper of a village of 600 inhabitants or even more, and as a house-drain is frequently dry for several hours at a time, it is obvious that where such large pipes are used there must be a considerable extent of surface on which sediment is deposited, and during the periods of minimum flow this deposit will decompose and give off foul gases. If the house-drain is properly disconnected from the main sewer, a considerable amount of these gases will be carried away into the atmosphere, but the tendency of the remainder will be to move towards the interior of the house on account of the absorptive influence of the warmer air within. The author contends that this generation of gases in the house-drain is entirely adverse to the principles of sanitation, and that its prevention lies in the use of smaller pipes.

Taking the average number of inhabitants of a town house at ten, and allowing 30 gallons of liquid matter to be discharged per head per day, the total volume would be 300 gallons per day, and of this amount one-half must be reckoned as being discharged in six hours, thus giving 25 gallons per hour as the maximum flow to be provided for. To this amount must be added the rainfall from the roof and areas, which as a rule in town houses is taken into the sewer. The superficial area to be considered under this heading varies from 1000 to 10,000 square feet; taking 6000 square feet, which is considerably in excess of the average, and allowing for 1¼ inches of rainfall per hour, thus providing for heavy thunderstorms, the total volume of rainfall to be dealt with would be 3900 gallons per hour. The maximum hourly discharge of sewage and rainfall combined would therefore be 3925 gallons, or 65·4 gallons per minute, and a 4-inch pipe will discharge this amount when running full at the very flat gradient of 1 in 207·36, the velocity produced being 2·02 feet per second which is barely sufficient to make a drain self-cleansing.

As the conditions on which these figures are based are only possible during an exceptionally severe thunderstorm, it is evident that without special flushing arrangements even a 4-inch drain can scarcely be made absolutely self-cleansing, especially when it is laid at the ordinary gradient of 1 in 60, at which rate of inclination it would require nearly double the maximum volume given previously, viz., 65·4 gallons per minute, to make it run full. The author therefore considers that, under ordinary circumstances, a 4-inch drain is sufficient for an average sized town house, and that a 6-inch drain is too large to be kept free from deposit, more particularly as the majority of the pipes discharging into it are three inches or less in diameter. Baths, lavatories, and sinks never have waste pipes exceeding two inches internal diameter, and it is the exception to find more than one appliance being discharged at a time. The soil-pipe is the only pipe of larger size which ever discharges at full bore, and the amount discharged at one time, viz., two or three gallons at the most, is insufficient to make a 4-inch horizontal drain run even half-full for more than a few feet.

Automatic flushing is of the greatest assistance, not only in keeping a drain free from deposit, but also in the removal of grease, and should be adopted in all cases where possible, and more particularly in cases where, from the depth of the main sewer, the inclination of the house-drain is less than 1 in 60.

The collection of grease by means of a grease-trap is open to the objection that its removal is left to human hands, and experience shows that duties of this kind when entrusted to servants are frequently neglected. The use of automatic flushing renders both grease-traps and human aid unnecessary, and the author finds that the most satisfactory results are obtained by flushing direct into the sink waste pipe, the trap being ventilated to counteract syphonage. The falling body of water has sufficient power to break up the grease congealed in the waste pipe while the continued flush carries the broken grease through the drain into the sewer, and the fragments being cold, there is no adhesion to the sides of the drain. An arrangement showing the method described is illustrated by Fig. 15.

The author maintains that by using a 4-inch drain laid at a uniform gradient not less than 1 in 60, aided by automatic flushing, all refuse and other matters discharged into the drain will be removed in the shortest time and with the minimum of deposit, and to those who say that a 4-inch drain would be choked by such extraneous objects as a duster, a medicine bottle, or a hair-brush, the saying "a place for everything and everything in its place" may be aptly quoted, as a house-drain obviously cannot be the proper place for a hair-brush, and the removal of such articles can be effectually provided for by making every length of drain accessible from inspection chambers; but the author's experience is that such objects do not usually get beyond the closet trap.

With reference to the water supply, this is a matter depending so largely on the regulations of the various water companies, that the author proposes dealing with it very briefly. Where the supply is intermittent the cisterns should be so arranged as to hold a total supply equal to at least two days' consumption, based on the maximum number of occupants at 30 gallons per head per day, and should in all cases be provided with movable covers and be placed in easily accessible situations. If in exposed situations the cisterns should be protected against frost, and this will apply equally to rising mains and service pipes throughout the house. Stop-cocks should be fixed on both rising mains and services, so that any one branch can be shut off if required without interrupting the others, and particularly in the case of hot-water pipes, but all the stop-cocks, unless fullway, should be a size larger than the pipe to which they are fixed, as otherwise the flow will be throttled. All cistern overflow pipes should end in the open air and in proximity to a properly disconnected rain-water head or gutter.

There is one point under this heading to which special reference may be made, viz., the question of separate cisterns for closet services and for domestic use, the popular belief being that this is in all cases an absolute necessity, and that where the same cistern supplies both closets and drinking water, the result must be contamination and pollution.

The author contends that in one general and frequently recurring instance this belief is erroneous, and that where well-made modern valve-closets are used, contamination of the cistern supply by sewer or drain gases is an impossibility.

Take for example a cistern supplying a valve-closet in a town house. In order to pollute the cistern, gases from the drain would have to pass firstly the trap under the closet, and in the event of this they would be carried off by the small pipe ventilating the valve-box; secondly the basin valve, and thirdly the standing water in the basin. If the gases could get thus far, they would then be liberated in the room containing the closet, and in this diluted condition would have to pass, fourthly, the supply valve to the basin, and fifthly, through a column of water varying from 10 to 60 feet in height.

It is possible, though highly improbable, that under the exceptional circumstance of the cistern being empty, germs or effluvia from fresh soil in the basin might find their way into the service pipe, but, as the supply valve is opened by the same action as the basin valve, the passage of such germs or effluvia would have to be instantaneous, and, though admittedly possible, pollution of the water in the cistern from this source is extremely unlikely.

The author therefore submits, without in any way advocating the principle of a single cistern for the dual service, that, in the circumstances described, and illustrated by Fig. 16, there can be no pollution under normal conditions, and that water from such a cistern could with safety be used for drinking.

The concluding object, viz., the construction of the entire system of house drainage in such a manner as to prevent foul gases or currents of polluted air from entering the house, may be dealt with as embodying the various points already advocated in this paper, which, briefly, are:—

(*a*) The disconnection of the house-drain from the main sewer by means of an intercepting trap and air inlet shaft.

(*b*) The maintenance of air circulation throughout the entire system by means of the soil-pipe, anti-syphonage, and subsidiary ventilating pipes.

(*c*) The disconnection of the rain and waste-water pipes from the house-drain by means of gullies and the treatment of the waste pipes as described and shown in Fig. 14.

(*d*) The separate and efficient trapping of every appliance, together with the necessary precautions against trap syphonage.

(*e*) The delivery into the main sewer of all matters dis-discharged into the house-drain before decomposition can set in, without leaving any sedimentary deposit in the system, as effected by the combined use of 4-inch pipes and automatic flushing; and lastly,

(*f*) An abundant supply of water.

With these six points carefully attended to, the question of the best materials to use in order to prevent the leakage or escape of both gases and liquids can now be entered upon, and the author proposes dealing with it under the three following sub-headings, viz.:—(1) The underground drain; (2) the rain-water, soil, and waste pipes; and (3) the appliances.

With reference to the underground drain, the two materials in vogue at the present time are stoneware and iron. Where the former is used the pipes are usually jointed either with Portland cement or else with a mixture of rosin and asphalte; in either case the pipes should be laid on a bed of cement concrete carefully packed after the joint has been made, and surrounded on all sides with the same material at least 6 inches in thickness, as shown in Figs. 17 and 18, the latter being a cross-section.

Where iron pipes are used they should be coated inside and out with Dr. Angus Smith's solution, a preparation of tar applied at a high temperature, and the joints should be first caulked with oakum and then run with molten lead, the depth of lead in the socket being 4 inches. The thickness of the metal of the pipe should be at least three-eighths of an inch.

Comparing the iron and stoneware drains, the great objection to the former is the cost, which the author finds to be about 30 per cent. more than that of stoneware; but regarding the security obtained by the use of iron there cannot be two opinions, this latter material being, so far as health is concerned, the most economical in the long run.

In the first place, there is a joint every 9 feet in an iron drain and every 2 feet in a stoneware drain, and as it is generally accepted that the fewer joints there are in a drain, the fewer chances there are of leakage, the advantage of the former over the latter would be in the ratio of 4½ to 1, while the time occupied in laying a given length in each material, and consequently the cost of labour, is distinctly in favour of the iron drain.

In the second place, there is a greater likelihood of a stoneware drain giving way, owing to settlement or to vibration, such as that produced by an underground railway or by heavy vehicular traffic, by reason not only of the increased number of points of possible rupture, but also of the more brittle nature of the jointing material (cement) as compared with lead.

In the third place, an iron drain will stand a very considerable pressure before giving way; whereas a stoneware drain, although it may stand a pressure of 3 or 4 feet head of water at first, in many cases will be found, from the causes last mentioned, to leak after a few months, especially when subjected to the strain produced by the head of water involved by automatic flushing.

In the fourth place, it is always a difficult matter to make a perfectly sound joint between lead and stoneware, such as the junction of the soil-pipe with the underground drain, and the results of many tests show that this joint is one of the weakest points of the stoneware system, whereas by means of a brass caulking sleeve or ferrule soldered to the lower extremity of the soil-pipe and run with molten lead into the socket of the iron drain-pipe, as shown in Fig. 19, an absolutely sound and lasting joint is obtained.

The author has therefore no hesitation in giving the preference to iron as the best material in the case of drains passing under occupied premises, and considers that the small extra cost is more than balanced by the additional security obtained. That iron drains have found favour in America may be judged from the fact that in New York and many other cities it is now compulsory for house-drains, whether external or internal, to be of iron to a distance of 10 feet on the sewer side of the interceptor, beyond which point stoneware may be used.

The rain-water pipes should be of galvanised iron. The ordinary painted rain-water pipe is simply a nuisance, the author having had numberless cases under his notice of these pipes choking from internal rust. The soil-pipes should be of hydraulic-drawn lead of substance equal to 8 lbs. per foot superficial; the portion of the soil-pipe above the highest closet, and acting as a ventilating shaft only, may be of 7-lb. lead, and in all cases should be of the same diameter as the soil-pipe itself. All joints on lead pipes should be wiped solder joints, but where external appearance has to be considered, astragal joints may be used.

Cast-iron rain-water pipes are frequently used for soil-pipes, but in addition to the very grave defect already mentioned, viz., the liability to choke from internal rust, there is another equally grave, and that is the shrinking of the jointing material, red lead, and the consequent opening of the joints. If cast iron be used for soil-pipes, it should be in the form of heavy-coated pipes with joints run with molten lead; but the author is in favour of lead, and lead only.

All waste pipes should be of strong drawn lead, the separate pipe from each appliance not exceeding 2 inches internal diameter; the size of the vertical stack-pipe, taking the wastes as shown in Fig. 14, being dependent on the number of appliances connected with the stack.

Anti-syphonage and ventilating branch pipes should also be of lead, those for traps of closets and slop sinks being 2 inches, and those for lavatories, sinks, and vent pipes to valve boxes being $1\frac{1}{4}$ inches internal diameter.

The final subject of appliances embraces such a wide field, that the author proposes limiting it, in the present instance, to the connections with the drainage system.

The treatment of sinks, baths, lavatories, and cisterns has been already dealt with; urinals in private houses are a never-failing nuisance, and can easily be avoided by the use of pedestal closets, but if they must remain, intermittent automatic flushing should be provided; the continuous dribble, so frequently found in railway stations and other public buildings, invariably retaining a portion of the urine and circulating it in the basin instead of carrying it off at once.

The one remaining appliance is the most important, viz., the closet, the three forms in general use being the valve, the wash-down or short hopper, and the wash-out. The latter (Fig. 20) may be summed up as a step backwards in an age of progress; the soil, when finally washed off the ledge or shelf on to which it is dropped, is driven against the side of the trap above the water-line, forming an incrustation which would throw off a most unpleasant effluvium or possibly dangerous germs in the room. In the hopper closet, Fig. 21, which is a wash-down, the soil falls at once into the water-trap, thus getting rid of the last-mentioned defect; but both these closets have two objectionable features, viz., the connections with the soil and ventilating pipes. The joint with the former is usually made by turning over the soil-pipe at the floor-level and forming a socket, into which the outgo of the closet is dropped, the collar on the latter being bedded on red lead. This material shrinks in time, and, in addition, the joint, which is on the drain or dangerous side of the water-trap, is disturbed, and runs the risk of being broken every time the closet is used. The joint for the ventilating pipe is made by slipping the end of the lead branch into a horn or socket on the closet trap and surrounding it with putty, a material which is about as suitable for this purpose as paper.

Another objection to both these closets, shown in Figs. 20 and 21, is the position of the socket taking the vent pipe. The rush of water, when the closet is discharged, carrying the stream against this opening, choking it eventually with paper and soil, and consequently nullifying the object of the socket.

By the use of a flanged lead trap, as shown in the wash-down closet, Fig. 22, a direct-soldered joint is made, not only between the trap and soil-pipe, but also between the former and the ventilating branch, while the joint between the basin and trap is above the water-line, and therefore on the safe side. The weight of the person using the closet should in all cases be kept off the basin by iron standards fixed to the floor, as, unless this precaution is taken, the joints are liable to disturbance.

The great advantage of pedestal closets is that no wooden enclosures are necessary, these latter only serving to harbour dirt, and in too many cases to conceal bad workmanship.

The flushing arrangements for pedestal closets still leave much to be desired. The discharging capacity of the waste-preventing cisterns is limited by most of the water companies to two gallons. This amount is quite inadequate for the purpose, and the limit should be raised to three gallons; while the noise made by the majority of these cisterns is a very objectionable feature.

The modern flushing-rim valve closet, Fig. 23, when well made and properly trapped, is without doubt the most satisfactory one for use in private houses. There is treble security against sewer and drain gases, as already pointed out in this paper and illustrated in Fig. 16; there is a total absence of the noise just mentioned; the soil drops at once into a large body of water, and when the valve is released this body falls suddenly into the trap below with such force as to carry the entire contents of the basin through the trap, and the risk of loss of seal from evaporation, to which all open-trapped pedestal closets are liable, is reduced to a minimum. In selecting a valve closet the following points are worthy of attention: the valve spindle should work through a gland and stuffing box in order to prevent the escape of gases through the bearings of the spindle; the flushing-rim should be continuous all round the basin, and the overflow pipe, which ought to be open at the top for inspection and cleansing, should be flushed at every discharge, and should be well trapped before its junction with the valve box; the handle should actuate the valve lever by means of a sliding link instead of being attached direct, as the latter method not only produces the unsightly defect of the handle being thrust on one side instead of always retaining a perpendicular position, but also produces friction and wear with their consequences; the valve box should have a separate ventilating pipe carried to the outer air, and the supply valve and service thereto should never be less than 1¼ inches diameter; and where the available head of water is 10 feet or less, it should be 1½ inches. In fixing a valve closet it is well to remember that the mechanism requires a certain amount of attention, and therefore the wooden enclosure should be made to open readily for occasional inspection.

In concluding this paper the author wishes to lay stress upon the necessity for testing the drains of every house, not only on completion, but also at regular intervals subsequently, as even the best planned schemes are liable to derangement from unforeseen causes. So far as the underground drain is concerned, the only safe and reliable test is that of hydrostatic pressure, this being the only one in any way resembling the pressure to which a drain is liable when a stoppage occurs. The drain, after being plugged at its lower extremity and slowly filled with water, should be allowed to remain absolutely quiescent for at least an hour; and if, at the expiration of that time, the water level shows no indication of subsidence, the drain may be considered sound. Smoke, peppermint, and other chemical agents, though useful in testing for disconnection and for the soundness of soil and waste pipes, are of no value whatever for testing an underground drain, and may be placed in the same category as the verbal assurances given by house agents and builders with which many people are satisfied. But there are doubtless many more who will agree with the author's final words, namely, that in all matters bearing on life and health "seeing is believing."

DISCUSSION.

The President said that he ventured to predict that Mr. Lawford would have a very hearty vote of thanks for bringing this paper before the Society. He had not attempted to absorb their attention with the horrible ancient history of sanitary science, but had brought them almost at once to modern practice. He had almost taken them to the stages at which they could, without much further knowledge of the subject, go and make the necessary connections for house drainage. He thought that they would all be very pleased with the diagrams. Mr. Lawford had evidently taken an immense amount of pains in producing them. They spoke for themselves, and would form a source of very valuable information when embodied in the 'Transactions.' A great deal of trouble had been expended also in bringing models to illustrate the paper. They were very much indebted to Mr. T. de Courcy Meade for placing models and apparatus for testing drains at the disposal of the meeting, which he felt sure would be glad to hear Mr. Meade's remarks regarding them. A subject of this kind ought to be brought before the Society periodically, because sanitary science was constantly changing; and what may have been considered perfectly right and safe ten years ago might now be held as absolutely wrong, or very nearly so. Mr. Lawford was already known to the Society of

Engineers as an author, this being the second occasion on which he had brought a subject before them. He (the President) had much pleasure in moving a hearty vote of thanks to the author of the paper.

Mr. H. H. Collins said that he was obliged for the opportunity afforded to him of most heartily seconding the vote of thanks. The paper was as practical a one as he ever had the pleasure of listening to. He had accepted the invitation to the meeting, imagining that whilst he should derive instruction, he should have some opportunity for a controversial encounter with the author upon some details of the subject; but he must deny himself that pleasure, and remain quiescent, as in almost every instance he cordially agreed with his views. All the elementary principles of sanitary science had been long ago conceded by those persons who were formerly disputants, and therefore, with regard to those first or elementary principles, there was nothing now left to contend about, although there might be some difference of opinion as to the practical application of the same. He did not quite agree with the author that "seeing was believing." The model on the table had been recently produced by Mr. Knight, the curator of the Sanitary Institute. He was sure that Mr. De Courcy Meade would wish honour to be given where honour was due. It was a valuable adjunct for showing that all those points on which the author had so strenuously insisted ought to be thoroughly maintained in practice. There were only one or two points upon which he wished to make some slight observations. In his own practice he had not always found it desirable to adopt the method illustrated in Fig. 5, where the air was supposed to be entering into the intercepting chamber and passing up the soil pipe. As a matter of fact, he had been spoken to by clients who complained very much of the intermittent effluvium which it occasioned, and which found its way into the kitchen windows. That was one reason why he was not in favour of adopting this system. Where possible he carried the inlet up to a high point, but if he could not do this he turned the inlet into the street or into the forecourt belonging to the house, and quite away from the windows, doors, or other inlets to the house. He was quite aware that the expense and other obstacles might sometimes preclude this being done. At the same time, to create good sanitation was worth some sacrifice. They could not obtain good plumbing and good drain work if their hands were too much tied on the score of expense. It would be recollected that in many recent ventilating apparatuses the principle upon which they were designed was that, when water fell from any height, air followed it, and was thus propelled into the room, etc. The same thing, of course, occurred in a soil-pipe every time the contents of a W.C. was discharged into it; the plug of water sucked the pure air down the soil-pipe, traversing the whole system of drain pipes, cleansing, oxydising, and sweeping out any impurities they might contain.

The iron pipes which the author had suggested were certainly the only right means for carrying away the sewage and drainage. If the pipes were properly laid, there should be no possibility of any deposits that could produce sewer gas. The sewer gas was *the* gas which accumulated in the sewers, and not that which was in the house pipes. By the ordinary arrangements, supposing there was any lodgment in the house-drains creating impure air, they would be sweeping it inwards, instead of, as he advocated, outwards. No one would wish a servant to sweep all the dirt to the inside of the house, even if there were half a dozen servants to take it away afterwards. Every time the closet was used, the water in the soil-pipe, with the air that followed it, acted as a purifier, and as a broom sweeping away and oxidising all impurities it encountered, and this, he thought, was the correct system to advocate. It certainly conquered the difficulty of foul air escaping through that which is intended to be the inlet, but of course it could not always be done. It sometimes happened that where appearance was studied there was an objection to carrying up soil or other pipes outside the building. He could point out a great many first-class houses where he had applied this system with very great success. An extract pipe as suggested did not require to be very thick. He was satisfied with 6 or 7-lb. lead, for it had nothing to do but take the air away. He was glad to see that the author mentioned another matter which was almost as important as the question of drainage, and which, in fact, was collateral with it. That was the question of ground air. Of course if they had a contaminated soil, all the labour, thought, and study of the sanitary engineer would be lost if they did not seal their soil in the same way as they sealed their traps. When the engineer was having his drainage laid in he should be most careful that all sloppy contaminated soil should be removed, and should insist that the ground be covered with good concrete, not that made with burnt ballast, which would suck up all the humid foulness of the ground, but good ballast concrete, covered with a Portland cement surface. The author had referred to cowls. It was admitted by that ever-to-be lamented eminent sanitarian, Dr. De Chamont, and by Sir Douglas Galton, that the appliances which were used in making the Kew experiments were faulty. He was quite of the same opinion as the author that the majority of the cowls manufactured were useless. Inventors of cowls brought to one's offices very pretty models offering every inducement for their adoption, being accompanied by testimonials of great authority and recommended by most eminent engineers, doctors, &c. Cowls grew with mushroom rapidity. One cowl which he had used and thoroughly tested had given him great satisfaction. It was invented by a Frenchman, Captain Papier, and he, Mr. Collins, had used hundreds of them with success. He noticed upon looking at Diagrams Nos. 13 and 14, that the ventilating pipe which was so useful in preventing syphonage was omitted. He almost thought that if that was applied to No. 13, then No. 13 would be as good as, or, in fact, better than No. 14. Here he would interpose the remark that in his own practice he never brought the waste pipe into or over a gully, but he brought it over a channel pipe some 18 inches away from the gully, so that any excrescent or disagreeable matter found its way to the channel and was there deposited. He thought that it was the duty of the head of the house, whether in high or low life, to look after these matters and correct them if found to be wrong. He believed that the more dirt was exposed to view the better. He had generally used glazed channel pipes, or Stiff & Sons' combined gully trap and channel. The gradient suggested by the author seemed to him very little in order to get the velocity named. With regard to size of pipes it must not be forgotten that these pipes were often stopped up with rubbish. Sometimes a dishcloth would be found in them. Some people used rag instead of paper, and threw it down, and though four inches might be sufficient theoretically for house drainage, he thought that 6 inches was the smallest pipe for soil drainage which should be used, and more particularly when they were told by the author of the paper that if the drain was properly laid and made, there was very little, if any, impure water in it. The author spoke of inspection chambers, but he did not think that he referred to making man-holes so that a man might get to the pipes, and not only flush them out with water, but cleanse them with rods and brushes, just in the same way as the sweep swept the flues of a house. At his own house he had a man in every three months, and had the drains swept out in the same way as he had his chimney swept. There was nothing occasioning inconvenience, nor was it a disagreeable operation, He must say that there was really one point in which he did not agree with the author, in that he did not agree with a 4-inch pipe, he thought a diameter of six inches was absolutely essential, and was the least which ought to be used. He should like to express the opinion, which he did wherever he could, that it was an iniquity upon the part of the water companies to prohibit water closets being supplied with a flush of more than two gallons of water. At least three gallons ought to be allowed. With regard to cisterns, if it were only as a matter of sentiment and not as a matter of sanitary knowledge, he should say that by all means the cistern containing drinking water should be free from any suspicion of connection with the water closet. Another point with regard to a cistern containing drinking water was that it should always be put in such a position as to be easy of access for cleansing, indeed, all cisterns should be located in an apartment specially designed and arranged to contain them.

Mr. W. LEE BEARDMORE said his attention was attracted to the tendency to angularity at the syphon trap, exhibited in Figs. 3 and 5; he thought this especially noticeable in Fig. 5, such tendency being liable to cause blockage of the traps. He thought the depth from the invert of the channel to the level of the water, forming the seal of the trap, very great, and that in such a case sewage matter passing down the channel and dropping into the seal of the trap would create considerable splashing in the upper portion of the trap, and, consequently, fouling of the drains. He considered that the inspection branch for examining the drain to the public sewer, shown above the syphon trap, placed at such an angle as represented, would ill admit of rods being passed down the drain for the purpose of clearing it. It appeared to him that in the fresh air inlet pipes shown, there were unnecessary bends, and a pipe carried from the manhole up to a chamber cut in the wall shown in the diagrams would admit of better circulation of fresh air through the drains, &c., as the air would pass more directly into the "disconnecting manhole," and friction in the bends would be avoided. He contended that it had been proved that when a flush passed down the main house-drain into the disconnecting manhole, there was a tendency to force foul gases which might be generated in the drain and manhole through the fresh air inlet pipe, and out at the grating, if there were no mica-flap, which he considered in the case of town houses very desirable. With regard to the disconnection of sink waste pipes, he always pursued in his practice the method adopted in Fig. 13. In such a case as illustrated in Fig. 14, it is quite possible that the grating of the gulley trap may become covered with old leaves, straw, and such like matter, and together with dust, &c., perfectly choking and sealing the grating, and he maintained that in such a case there would be no longer any "disconnection," whereas such was always guaranteed in the case of Fig. 13. He considered the arrangement described by Fig. 10 must tend to cause considerable splashing in the hopper of the gully trap. He agreed with the author to a great extent, that the danger was minimised in the case of water being supplied for drinking purposes from the same cistern which a valve-closet was flushed by, more particularly in the case of valve-closets without any overflow pipes, but he pointed out that where an overflow pipe was fixed in connection with the W.C., even when trapped, danger might arise, as it was rarely that the regulator of the closet apparatus was so adjusted that the overflow pipe was constantly flushed, and consequently, the "seal" of the trap would not be replenished, and would become useless, owing to evaporation and foul gases generated in the valve-box, would pass into the basin of the W.C., so that in the event of the cistern being temporarily empty, they might find their way into the cistern and contaminate the supply when again filled. Again, he thought it was opening a channel for insanitary practice, as he considered it was a great point never to make a sanitary maxim that could in the slightest degree be subject to misinterpretation, and, no doubt, if valve-closets were permitted to be supplied from the same cistern that furnished drinking water, some people might, in certain cases, be instigated to supply any W.C. whatsoever in a similar manner. Mr. Collins had advocated the carrying of the fresh air inlet pipe up to the level, at least, of the roofs of houses, but his experience was, that in such a case the fresh air inlet pipe, being about the same height as the foul air outlet pipe, there was a tendency to equilibrium and stagnation of gases in the drains and pipes, the heavy carbonic acid gas generated in the drains especially remaining at or about the lowest point in the drains. In one case where his opinion was sought, he found that the usually accepted fresh air inlet pipe was carried up to about the level of the roof of the house, and at a few feet above the area level there was fixed in this pipe what might be described as a small window which could be unscrewed and removed, and in the pipe behind the window was a gas-burner, evidently intended to be kept burning, so as thereby to induce an up-draught through the shaft, and serve as an up-cast shaft with the aid of the gas-burner. However, the burner was not alight and had not been in use for some time. On lighting the burner, he (Mr. Beardmore) found the flame was immediately extinguished, and after several futile attempts to keep it alight he gave up the attempt. This, in his opinion, clearly demonstrated that, in such cases, equilibrium practically took place, and no current of a useful kind was induced, the heavier gases (carbonic acid especially) remaining at or about the lowest point in the drain. He concluded by observing that he was, apart from the foregoing, convinced, owing to the experiments carried out by Mr. G. A. Pryce-Cuxson and himself, which conclusively proved the fact that the fresh air inlet pipe should be at or about ground level.

Mr. De Courcy Meade said that he had come to the meeting with the intention of criticising the paper, but he found that most of the points dealt with were those generally acknowledged amongst sanitary engineers of the present day. Turning to the glass model on the table, Mr. Meade stated that it was a copy of the original which he had seen at the Sanitary Institute. He had been so much struck with the manner in which it practically exemplified the passage of water, and syphonage in pipes, that he immediately ordered one from the inventor and maker, Mr. Knight (the speaker then, in various ways, showed the action of the model by pouring coloured water into it).

He thought that too much stress could not be laid upon the importance of having inspection chambers at the back of the premises, in addition to the intercepting chamber at the front. Sweeping eyes were absolutely necessary, because occasionally certain matters found their way into the best laid pipes, and could not possibly pass through them by mere flushing. He, therefore, thought that it was absolutely necessary, for the security of the householder, to have a means of sweeping a drain from end to end. There were various descriptions of air-tight covers which would render it almost impossible for sewer gas to escape from the inspection chamber, however near it might be to a window. One of the diagrams shows a trap between the sewer and the house with merely an inspection pipe. He was inclined to say that he would rather see no trap at all than such an arrangement. He had had to take out scores of such traps, and he invariably found that they were clogged with grease. There should be an inspection chamber of sufficient size for a man to enter so that there might be proper control of that weak point of the drain, viz., the trap. He did not quite agree with the author with regard to smoke tests. He believed that they were most useful as a preliminary test, although he would not think of applying them as a final test. If there was a weak point in the pipes or fittings it would be sure to show itself under the smoke test if properly applied. The test as to the soundness of a drain would of course be the hydraulic test, as the smoke test alone could not be depended upon for that purpose. Sometimes in an old building the engineer did not know where the drains were, and even when a plan could be found it was often misleading. In such cases the smoke test was most valuable. In an old building near the place where they were assembled he had, by means of the smoke test, found the existence of drains in a place not shown upon the plan, and of which the owners had no knowledge; there was a bell trap (minus the "bell") in the centre of the building, close to the air inlet of the heating apparatus, which was used for conveying heated air into an apartment where many people assembled. If it had not been for the smoke test he might have failed to find that bell trap. Mr. Meade then exhibited and described a rubber-lined canvas bag drain stopper with a small inflating pump, and several other kinds of drain stoppers, and machines for testing drains by smoke and chemicals, which he had used and found valuable.

Mr. Tidman said that he perfectly agreed with the paper except in one or two instances. He disapproved of the "open grating" air inlet. In the district between Edgeware-road and Tottenham Court-road, a great many of the larger houses were drained upon that principle, and several people had objected to his putting valves on the inlet. He had tested them with smoke and the result was that the front area was filled with smoke, when the upper w.c. was flushed. As to valves, he preferred the wall valve to the ordinary pipe valve. If this valve was placed about 2 feet 6 inches away from the floor-line it was above the kicking line and below the finger line, and was, therefore, less liable to damage. The air space should be kept as large as possible, and he used 11 inches by 7 inches generally; this checked the out-going of the foul air during the falling of the water, and then immediately resumed its function of supplying fresh air. As to the drain-pipe joints, asphalte and resin were perfectly useless. At Turnham Green drains had had to be taken up and relaid with cement joints because the action of the acid in the sewage had entirely eaten away the black matter. He had given up using pipes with this black joint except in conjunction with cement, that known as Hassall's joint being the best. He agreed with all that had been said about keeping cisterns accessible; but they also wanted to be covered up. He had found dead mice in a drinking-water cistern, which had not been covered up. Sanitary inspectors had told him that they occasionally found pieces of meat in cisterns, probably dropped there by cats. With regard to the smoke tests, he agreed with Mr. Meade that it was very useful for the first test, but it would not do for the final one. It enabled the inspector to test a drain before it was opened, but nothing short of the hydraulic test was reliable. Another very useful appliance was a little ball called an "explorer," which held a glass tube and was provided with a spring-cord and trigger, the explorer was inserted in the drain or soil pipe, through a closet or gully trap, and then the string was pulled and the glass was broken, and a very pungent odour was given off. By this means any fault in a joint could be detected. The system advocated by Mr. Lawford was one he, Mr. Tidman, had carried out for years, and the paper had been a very interesting one and the vote of thanks was well deserved.

Mr. W. D. Scott Moncrieff joined with previous speakers in thanking Mr. Lawford for his excellent paper. Mr. Lawford had mentioned that he believed the cost of cast-iron pipes was

30 per cent. greater than that of earthen pipes. Of course, a great deal of the cost of laying drains was common to both kinds of pipes; and therefore he should like to know whether Mr. Lawford's remarks referred to the initial cost of the two different materials, or whether he meant 30 per cent. on the cost of the work as a whole. With regard to the junction between lead and earthenware there was certainly a standing difficulty, and they were practically confined to the use of some hard-setting cement which, of course, did not make a joint by any means so satisfactory as that shown in Fig. 19. Therefore Mr. Lawford was right in pointing out the very great advantage which existed in the case of cast-iron pipes when lead pipes had to be connected with them. In speaking of earthenware drains Mr. Lawford omitted to refer to one important point. It was a question with many engineers whether, in the case of an arrangement as shown in Fig. 3, the earthenware drains should be tested by inserting a plug in the pipe as it enters the man-hole, by the arrow. If the plug was inserted there, of course the man-hole itself, including the bottom and the sides, would be untested by the water. The water-test would only apply to that portion of the drain which lay on the house side of the drain beyond the plug in the direction of the arrow; but if there was, as there ought to be, an additional inspection chamber at the back of the drain, the water would rise into it, and there would not only be the difficulty of localising any defect if it occurred in the brickwork, but there would also be the difficulty of dealing with a very weak joint; that is, if they were depending, for the purpose of having a satisfactory test, upon the contact of the glazed surface of the pipe at the point at which it pierced the brickwork. It was needless to say that a glazed surface in contact with cement, especially when the work was carried out by an ordinary workman, was a very unsatisfactory method of retaining water. This was a weakness which ought to be got rid of. There was an obvious advantage in having an air-tight cover, as in Fig. 3, on the upper line of the half-channel; and that, of course, was only to be obtained in a satisfactory form in a cast-iron structure. Mr. Lawford spoke of Dr. Angus Smith's composition as tar used at a high temperature. It was, in fact, a mixture of coal-tar with coal-oil. The mixture was discovered by Dr. Angus Smith while he was making experiments with Mr. Young in the treatment of hydrocarbons, before the discovery of paraffin. There was no difficulty in specifying iron pipes dipped in Dr. Angus Smith's composition. He would suggest that a commercial profit might be made by establishing a place in London where the process could be carried out. He believed

that there would be a large demand for the treatment. As regards the efficiency of the solution, Sir Robert Rawlinson had a pipe which had been treated with Dr. Angus Smith's preparation, and had been in the ground for twenty-eight years without showing any great sign of rust. When the solution was applied at the proper temperature, the coating which it formed was neither brittle on the one hand, nor soft on the other, but hard and tough. He was glad that Mr. Lawford and others had inveighed against the short allowance of water afforded for flushing purposes by the water companies. He could not understand how such a state of things had been so long allowed to continue in a great community like London. A very strong point which the water companies made against automatic flushing was that it went on day and night. As a means of getting over that objection, he had suggested that the flushing apparatus should be worked by an electric clock which would make contact during the day, and not during the night. He had been very much interested in Mr. Collins's practical remarks. He believed that Mr. Collins would agree with him that sanitary experts had used the mica valve and inlet arranged, as shown in Fig. 5, very much because others had done it. There seemed to be a practical difficulty in getting the mica valve to work satisfactorily. He believed that the best form of drainage for a house consisted of iron pipes laid through a subway and carried on chairs. That was a rather luxurious mode of drainage, but he had had some opportunities of carrying it out, though they had not been very frequent. In the case of the Foundling Hospital he utilised the old sewers as a subway, and found this an excellent plan. They were cemented at the bottom, and whitewashed, and they formed an excellent subway to this day, affording ready access to all parts of the drainage. In the case of a large new building it would be worth while to adopt a similar plan.

Mr. CHARLES E. GRITTON said that, with regard to ventilating pipes from water-closet branches, the author had recommended taking them above the roof; that, he thought, was very often a waste of money. The best and neatest way, he considered, was to branch them into the soil-pipe ventilator, some 4 feet above the top connection. With regard to the use of iron, he was strongly of opinion that it was rapidly becoming recognised as the proper material for drainage—at any rate, under houses in this country. As had been stated to-night, and as many of them knew before, it was practically the only material allowed in the United States. He was rather surprised that no mention had been made of a very good way of preserving iron—the Bower-Barff process. This he had used somewhat extensively in draining Government and other buildings. He did not agree with the statement that iron cost some 30 per cent. more than stoneware, as it could be put down more quickly; and concrete, time, and labour were saved by its use. Instead of a house having to be turned upside-down for a month or six weeks, the iron pipes could be put down in a week or a fortnight. With regard to gullys, he was now in the habit, in his own practice, of insisting upon having them *circular* in plan, and of rounded section wherever possible. Square gullys should be avoided. There was a little thing in Diagram 22 which seemed to him might be a weakness, viz., the distance between the trap and the anti-syphonage pipe. Some time ago he had to drain a large school in which that plan was carried out exactly as it was shown in the diagram, and the result was not at all satisfactory. Until the anti-syphonage pipe was lengthened and brought nearer to the out-go of the trap, they were no better off than if they had no syphon traps at all—as trap-syphonage constantly occurred—except that there was ventilation. He did not quite agree with the statement of the author that the best way of treating a trap receiving the greasy waste water from the scullery sink was to take the flushing-pipe into the waste-pipe, although that method sometimes worked admirably. He thought that they were all agreed that a closet basin was much more self-cleansing if it had a flushing-rim than otherwise. There were gulleys made with flushing-rims for this very purpose (Winser's & Hellyer's), and they worked better than anything that he had seen. They heard it frequently stated that drains were not made to carry away foreign bodies; but such things could not be shut out. One of the oddest experiences which he had had was that of finding a disconnecting trap and chamber absolutely full of oranges: it was in the house of a German family who consumed a large quantity of oranges. They were in the habit of biting a hole and sucking the juice, and then throwing the orange away. The wedged accumulation of swollen oranges in the lower portion of the chamber was as solid as if it had consisted of puddled clay! Housemaids' brushes and tooth brushes were very often found in drains. One argument against using stoneware pipes was that they were very much at the mercy of the workmen using "hot" cement for the joints. At the end of a few weeks they might find every socket in the drain broken through the expansion of unslaked particles of lime. He had found this in a number of cases. With regard to the sarcastic statement that cowls did nothing but "keep out the rain," that was really a libel upon *good* cowls. He used cowls almost constantly, because they prevented "down-blow," and consequent trouble at low-level air inlets. By a "good" cowl he meant one designed with a "full-way" through it, having no reduction of sectional area at any point, and consequently offering no resistance to the rising air column; such as Stevens's fixed cowl and Hellyer's double-cap terminal.

As regards pedestal closets, these should never be used up-stairs unless fitted with LEAD traps, such as Winser's "Puro," Bolding's "Kenon," or Tylor's "Column."

He considered the custom of certain medical and other theorists of leaving outlets unprotected, and equally defenceless low-level inlets close to windows, so dangerously foolish as to be almost criminal.

Mr. GOYMOUR CUTHBERT said that in respect to the new safeguards which had been introduced into sanitation within the last few years, there had arisen the question of who should guard the safeguards. Many of the safeguards had introduced fresh dangers, and he supposed that it was necessary and natural that it should be so. The one to which he wished particularly to draw attention was the danger of gases escaping from the upcast shafts, and coming back into windows and down chimneys. There was more danger of this happening than some persons were ready to admit. During the last summer he was called in to the apartments of a client who resided on the top floor of a series of flats in a very fashionable position, and let at a very high rent. He found that the soil-pipe had been carried a foot or two above the topmost windows, which were all dormer windows. Experiment satisfied him that there was very little doubt that the attempt to relieve the drains in the house had eventuated in the gases coming out of the upcast shaft and being driven into the open windows of the flat. Another danger existed when they came near to chimneys. Those persons who lived in London knew how constantly the smoke from a house went down the neighbour's chimneys; and he had very little doubt that when there was no smoke the gases from the neighbour's upcast shaft also went down the chimneys. Unfortunately, the ordinary plan of a London house lent itself to such a result. The flues immediately contiguous to the shaft of one house belonging to the adjoining house, the occupier of which would thus suffer from an arrangement as to the very existence of which he would probably be ignorant. He thought that there was an opening for those gentlemen who devoted themselves exclusively to such matters to guard against the danger which he had described. He thought, too, that practically they put too much faith in the air-tightness of the air-tight inspection cover. This was a matter which constantly required looking after. As to iron pipes, he still looked upon them with slight distrust. With regard to Dr. Angus Smith's solution, it would not always be placed evenly and properly all over the iron, and a decomposition of the iron would result. They knew how completely an iron down-pipe which was not internally protected, and which only had rain water through it, would disintegrate, and he feared that if iron were generally adopted they would find new dangers arising from it. He must confess that he still thought that stoneware pipes laid on concrete and thoroughly tested afforded something upon which they could depend.

Mr. FREDERICK HOVENDEN said that eighteen years ago he built the house he now resides in, and he then adopted every one of the fundamental appliances which had been illustrated this evening. He very much questioned whether any one had before drained on the same principle. He thought that he might claim to be the father of the present system. The advantages of the system were so obvious, that he wrote to the *Times*, describing what he had done, but he could not get the letter inserted. Compared with the processes adopted by the author of the paper, there were one or two differences which he had adopted. First, he had a man-hole about 10 feet deep, and this was not closed with slabs, but open and only protected by a grating. That grating was about 6 feet from the side entrance to the house. During these eighteen years he had never had the slightest discomfort from the man-hole. Thus, this ventilating shaft, the man-hole, was fully exposed to the external gases in the atmosphere, and he was able at any time, without lifting up any lid, to go and see how the drains were working. The surface drainage pipes pierced the sides of this man-hole, and he was able to look down the shaft and see if this surface drainage was working properly. He disapproved of the contracted inflow pipe protected by a talc valve. It seemed to him to be calculated to get out of order, and to obstruct the diffusion of the noxious gases. One great point which he thought had not been fully appreciated was the importance of the reaction of the gases themselves in this air chamber or man-hole. This should be as large as possible, to permit of a diffusion of gases before they arrive at the surface, so that the noxious gases, which are very small in quantity, should be diluted before they arrive at the surface, and thus be rendered innocuous. At the present moment he was building two houses, and he was going to use exactly the same arrangement as he had described as now in use. He was of opinion that the proper dimensions of the pipe from the house to the man-hole should be 4 inches. Curiously enough, he is prevented from putting down pipes of this dimension by the local sanitary authority, who insists upon a 6-inch pipe!

Mr. MAX CLARKE said that he wished to call attention to a single point, and that was that he had found from experience that in the case of man-holes built with a flat floor, like one shown in the diagram, the water rose up at every flush and covered the bottom of the man-hole with very disagreeable material. If the surface was made with a very steep angle the excreta and other substances would be washed down, and would go into the pipe. Some years ago he laid down an iron pipe which was prepared by the Bower-Barff process. It was the suction pipe of a pump; about three years after his client wrote to him to say that the pump would not draw any water. He (Mr. Clarke) had the pipe taken out, and it was found to be perforated with innumerable holes. That experience would be against the use of pipes prepared in a similar manner for drainage purposes.

The hour being somewhat advanced, the President requested the author to reply in writing to the discussion.

The author sent the following communication in reply to the discussion. It appeared that the principal point raised was in regard to the ventilation of the house-drain and with special reference to the position and protection of the fresh-air inlet, and one general result of the discussion pointed to the fact that a low-level inlet was absolutely necessary. The high-level inlet shaft described by Mr. Collins was certainly open to the serious objection brought against it by Mr. Beardmore, viz., that there was a tendency to equilibrium caused by the collection of the heavier gases, such as carbonic acid, at the lowest point of the drain, thereby virtually causing the formation of an air-trap in the drain itself.

The protection of the inlet-shaft by means of the customary mica flap was generally advocated, but a point raised by the author, namely, the adoption of a double outlet, appeared to have been entirely overlooked during the discussion, his own experience having led him to conclude that where the anti-syphonage pipe was brought down into the same chamber as the soil-pipe, the air in the horizontal drain, displaced by the discharge down the soil-pipe, was driven up the anti-syphonage pipe, instead of forcing the inlet-shaft, as was generally believed.

He had carried out several experiments on this point with satisfactory results, and he might add that his opinion as to mica inlet valves being unnecessary was confirmed by that well-known authority on sewer and drain ventilation, Mr. W. Santo Crimp.

The model exhibited by Mr. Meade cannot, in the author's opinion, be in any way regarded as a fair test of trap-syphonage, the conditions differing so widely from those of actual practice. For instance, in the model the soil-pipe and the horizontal drain were both of the same size; the intercepting trap was placed close to the foot of the soil-pipe, and most important of all, the amount of water liberated at each discharge would be equivalent to a flush of ten or fifteen gallons in the ordinary closet. Under these conditions it was not surprising to see the traps in the model forced, and the author has no hesitation in stating that if an actual model of a well-drained town house was made to scale, the results would be very different, though he certainly thought that every credit should be given to Mr. Knight for bringing before the general public an ingenious invention exemplifying some of the principal objects of house drainage.

The advantages of iron pipes, for drains passing under occupied premises, appeared to be generally recognised, and in answer to Mr. Scott Moncrieff, the author has pleasure in giving the figures on which he based his comparison of cost between the iron and stoneware systems. Taking excavation and surface work as common to both systems—the stoneware drain works out to 1*s.* 8*d.* per foot run, made up as follows :—4-inch stoneware pipe per foot run 4½*d.* ; laying and jointing per foot run, 2*d.* ; bed of concrete 1 foot by 1 foot 6 inches by 1 foot 6 inches, as shown in Fig. 18, equal to 2 cubic feet per foot run, taken at 15*s.* per cubic yard, works out to 1*s.* 1½*d.* per foot run—totalling these three items, the prime cost amounts to 1*s.* 8*d.* per foot run.

A 4-inch coated iron socket pipe, weighing 18 lbs. per foot run, costs 1*s.* 6*d.* per foot; laying 2*d.* per foot; jointing 7*d.* per foot run, as detailed, viz., one joint takes 13 lbs. of lead at 2*d.*, say 2*s.* 2*d.*, and allowing 2*d.* for oakum, 2*s.* 4*d.*; labour, fuel, and clay, 2*s.* 6*d.* per joint, total per joint 4*s.* 10*d.*, and with one joint to every 9 feet; this is as nearly as possible 7*d.* per foot—totalling these items, the prime cost amounts to 2*s.* 3*d.* per foot run, or as nearly as possible 30 per cent. more than the cost of stoneware.

Mr. Gritton states that he has found iron drains actually cheaper than stoneware; the author has frequently, during the last few years, invited alternative tenders for iron and stoneware systems, and has never once found the difference less than the percentage stated in the paper, and in the majority of cases it has been exceeded.

In conclusion, the author expressed his opinion that while the fundamental laws governing house drainage, as originally laid down by Sir Robert Rawlinson, Mr. Rogers Field, and other eminent sanitarians, remain practically unchanged—the carrying out of the details is, of necessity, a matter in which opinions frequently clash, and it is by the comparison of these opinions, accompanied by the results of actual practice and experiment, that progress is made in sanitary science.

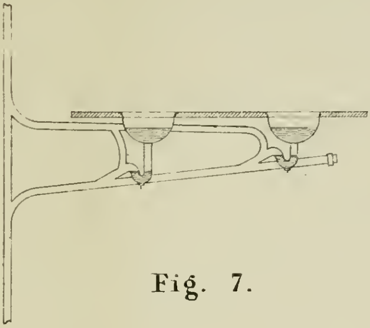

Fig. 7.

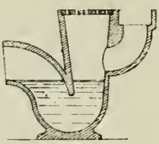

Fig. 10.

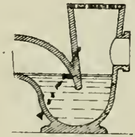

Fig. 11.

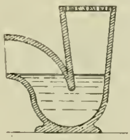

Fig. 8.

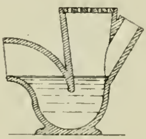

Fig. 9.

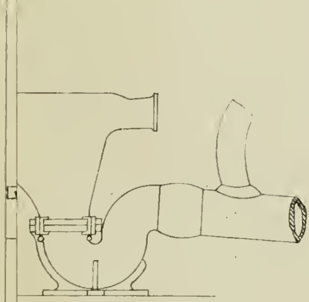

Fig. 22.

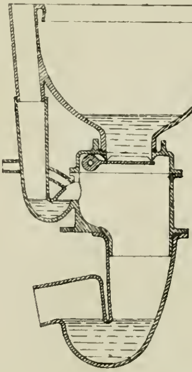

Fig. 23.

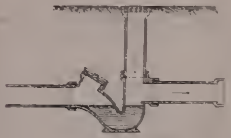
Fig. 1.

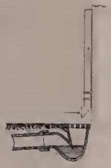
Fig. 2.

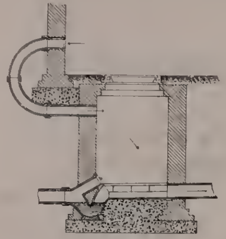
Fig. 3.

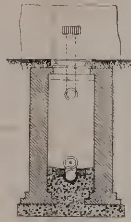
Fig. 4.

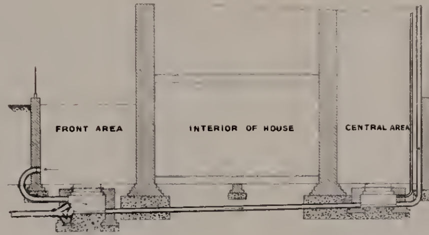

Fig. 5.

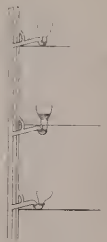
Fig. 6.

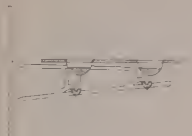
Fig. 7.

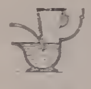
Fig. 10.

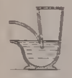
Fig. 8.

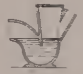
Fig. 9.

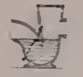
Fig. 11.

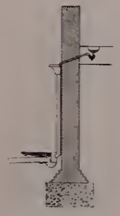
Fig. 12.

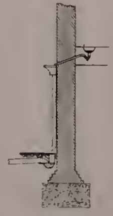
Fig. 13.

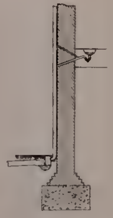
Fig. 14.

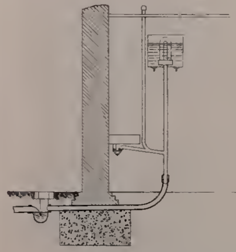
Fig. 15.

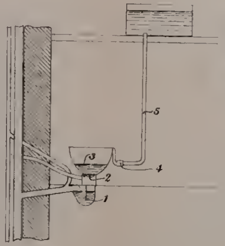

Fig. 16.

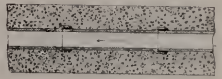
Fig. 17.

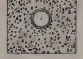
Fig. 18.

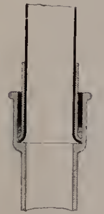
Fig. 19.

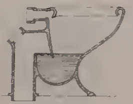
Fig 20.

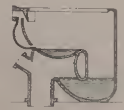
Fig. 21.

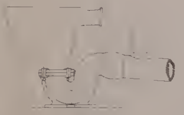
Fig 22.

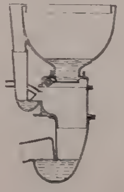
Fig. 23.

E & F N Spon, London & New York

Obituary.

Robert King (*Member*) died from an acute attack of pneumonia on the 27th of March. He was born in Ayr, Scotland, in 1822, and coming to London at the age of 20, attended during four years at Putney College of Civil Engineering, of which Dean Cowie was then principal. From there he entered the office of Mr. Ranger, C.E., who at that time was engaged in supplying Barnard Castle with water. He was also engaged in the office of Mr. Page, C.E., and for some time was on the staff of the Crystal Palace District Gas Company. In conjunction with Mr. Henry Palfrey Stephenson, C.E., he formed the Singapore Gas Company for lighting Singapore, and continued to be the engineer and secretary of that company from its formation till the time of his death. The success of this company is undoubtedly due in a great measure to the interest and energy he devoted to it. He was a member of the Society of Engineers from its formation, and ever took the greatest interest in its successful progress. He was also auditor of the Bombay, Ceara, and Georgetown Gas Companies.

Granville, George Leveson-Gower, second Earl of Granville (*Honorary Member*), died on the 31st of March, at the age of 76. Commencing his political career as an Attaché to the British Embassy in Paris in 1835, he in the following year relinquished that appointment upon his election as member of Parliament for Lichfield, and was Under-Secretary for Foreign Affairs in 1840–41. In 1846, by the death of his father, the first Earl, he became a member of the Upper House. During his career he held many of the most important offices of the State, including that of Vice-President of the Board of Trade from 1848–51, Secretary of State for Foreign Affairs in 1851–52 and again from 1880–85. He was President of Council in the periods 1852–54, 1855–58, and 1859–66. He was also Secretary of the Colonies in the periods 1868–70, 1870–74, and again for a short term in 1886.

In all engineering matters he took a great interest, being himself, through his Staffordshire estates, immediately connected with the production of coal and of iron ore, the latter being smelted in his own furnaces. He was further interested in the profession through his being an Elder Brother of the Trinity

House, an honorary member of Civil Engineers, and Lord Warden of the Cinque Ports, which post he held from 1865 to the time of his death.

PHILLIP CHEEK (*Associate*) died at Nice, on the 28th of April, at the age of 42. He was born at Boston, Lincolnshire in 1849, and was in the period 1867–75 engaged under the Burham Brick, Lime, and Cement Company. After that he became associated with the firm of Joseph Cliff & Sons, and remained with them for 16 years, up to the time of his death. His interests were principally in connection with sanitary work.

RICHARD WILLIAM COOPER (*Associate*) died on the 9th of October, aged 64. Although not an engineer, he was from the fact of his being a Parliamentary solicitor and agent, considerably interested in all civil engineering matters, and it is probable that his unflagging attention to his business, and the energetic manner in which he made the interests of his clients his own, in the many Parliamentary committee struggles with which he was associated, tended to shorten his career.

Amongst other matters of interest to the engineering profession with which he was concerned may be mentioned the celebrated patent case connected with the swivel which every one now wears on his watch chain, also the Parliamentary contests in connection with the gas supply of Birmingham and the outlying districts, and the subsequent arbitrations and litigation in the Courts. As some indication of the magnitude of the interests involved in those memorable struggles it may be mentioned that one arbitration alone (of four) lasted for six weeks, at a cost, according to a computation made at the time, of 3*l*. 3*s*. per minute! These proceedings in Parliament and in the Courts extended over a period of nearly ten years, and eventually resulted in each of the local authorities acquiring the control of their own gas supply upon terms which, while they gave cause for immense satisfaction to the local authorities in question, were a source of keen disappointment to those who at that time administered the municipal affairs of Birmingham.

He came to be regarded as an expert in gas legislation, and was associated in this way with many of the most eminent gas engineers of the past, including Stevenson, Penny and Spice.

In addition to the above, he was also connected as Parliamentary agent with the South Eastern Railway Company, the proposed Channel Tunnel, and Sir E. Reed's proposed Dover and Calais Tubular Railway.

SOCIETY OF ENGINEERS.

INDEX TO TRANSACTIONS,

1861 to 1891.

AUTHORS.

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
A.			
Abel, C. D.	The Patent Laws	1865	25
Adams, H.	President's Address	1890	1
Adams, J. H.	President's Address	1875	1
Adams, T.	The Friction of the Slide-valve, and its Appendages.	1866	6
Adams, W.	President's Address	1870	1
Alford, C. J.	The Mineralogy of the Island of Sardinia.	1879	93
,, ,,	Appendix to Above: Laws relating to Mining.	1879	106
,, ,,	Engineering Notes on Cyprus	1880	131
Alford, R. F.	The Fell Engines on the Rimutakai Incline, New Zealand.	1882	121
Anderson, Chris.	The Feasibility and Construction of Deep-sea Lighthouses.	1883	45
André, G. G.	The Ventilation of Coal Mines	1874	23
,, ,,	The Application of Electricity to the Ignition of Blasting Charges.	1878	123
Andrews, J. J. F.	Ship Caissons for Dock Basins and Dry Docks.	1890	189
Andrews, T.	The Strength of Wrought-iron Railway Axles.	1879	143
Atkinson, J.	Apparatus for Utilising the Waste Heat of Exhaust Steam.	1878	167
Ault, E.	The Shone Hydro-Pneumatic Sewerage System.	1887	68
B.			
Baillie, J. R.	President's Address	1889	1
Baldwin, T.	Single and Double Rivetted Joints	1866	150
,, ,,	Experimental Researches into the Nature and Action of Safety Valves for Steam Boilers, &c.	1867	23
Bamber, H. K.	Water, and its Effects on Steam Boilers.	1867	65
Bancroft, R. M.	Renewal of Roof over Departure Platform at King's Cross Terminus, G.N.R.	1887	125
Barker, C. M.	The Prevention of Leakage in Gas and Water Mains.	1869	79
Barker, E. D.	Hydraulic Continuous and Automatic Brakes.	1879	75
Barker, Capt. W. B.	International System of Marine Course Signalling.	1884	47
Barnett, S., junr.	The Value of Exhibitions as Aids to Engineering Progress.	1883	75

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Bartholomew, E. G.	Electric Telegraphy, irrespective of Telegraphic Apparatus.	1869	55
,, ,,	Electric Telegraph Instruments	1872	53
,, ,,	Electrical Batteries	1872	77
Beaumont, W. W.	Modern Steel as a Structural Material	1880	109
,, ,,	High Pressure Steam and Steam-engine Efficiency.	1888	221
Behr, F. B.	The Lartigue Single-rail Railway	1886	163
Bellasis, E. S.	The Roorkee Hydraulic Experiments	1886	41
Bernays, J.	President's Address	1880	1
,, ,,	The New Pits and Hauling Machinery for the San Domingos Mines in Portugal.	1879	29
Biggs, C. H. W., and Beaumont, W. W.	Notes on Electric Light Engineering	1882	23
Björling, P. B.	Direct-acting Pumping Engines	1877	79
Blackbourn, J.	The Action of Marine Worms, and Remedies applied in the Harbour of San Francisco.	1874	111
Bower, G.	The Preservation and Ornamentation of Iron and Steel Surfaces.	1883	59
Brothers, W. H.	Weighing Machinery and Automatic Apparatus in connection therewith.	1890	55
Bryant, F. W.	President's Address	1869	1
Buckham, T.	The Drainage and Water Supply to the Town of Fareham.	1869	41
C.			
Cargill, T.	President's Address	1877	1
,, ,,	Railway Bridge at the Place de l'Europe, Paris.	1866	191
,, ,,	Floating Breakwaters	1871	146
Carpenter, C. C.	Modern Coal Gas Manufacture	1891	61
Carrington, W. T.	President's Address	1865	1
Carter, J. H.	Roller-milling Machinery	1883	125
Cheesewright, F. H.	Breakwater Construction	1890	83
Church, Jabez	President's Address	1872	1
,, ,,	President's Address	1873	1
Church, Jabez, junr.	President's Address	1882	1
,, ,,	President's Address	1883	1
Colam, W. N.	Cable Tramways	1885	69
,, ,,	President's Address	1891	1
Colburn, Zerah	President's Address	1866	1
,, ,,	The Relation between the Safe Load and Ultimate Strength of Iron.	1863	35
,, ,,	Certain Methods of Treating Cast Iron in the Foundry.	1865	77
Conradi, H.	Stone-sawing Machinery	1876	135
Copland, H. S.	Modern Roadway Construction	1878	61
Cox, S. H	Recent Improvements in Tin-dressing Machinery.	1874	11
Cramp, C. C.	Tramway Rolling-stock and Steam in connection therewith.	1874	119
Crimp, W. S.	The Wimbledon Main Drainage and Sewage Disposal Works.	1888	73
,, ,,	Sewer Ventilation	1890	139

Author.	Subject of Paper.	Transactions.	
		Year	Page.
Crompton, E. S.	The Economics of Railway Maintenance	1870	101
Cullen, Dr. E.	The Surveys of Proposed Lines for a Ship Canal between the Atlantic and Pacific Oceans.	1868	15
„ „	The Panama Railroad	1868	39
„ „	The Isthmus of Darien and the Ship Canal.	1868	52
Cunningham, J. H. ..	Pin-connected *v.* Rivetted Bridges ..	1889	135
D.			
Danvers, F. C.	Engineering in India	1868	137
Davey, H.	Pumping Engines for Town Water-supply.	1867	88
„ „	Milford Haven and its New Pier Work.	1872	89
„ „	Recent Improvements in Pumping Engines for Mines.	1873	182
„ „	The Underground Pumping Machinery at the Erin Colliery, Westphalia.	1876	119
Day, St. J. V.	Recent Arrangements of Continuous Brakes.	1875	87
E.			
Edwards, E.	Utilisation of Waste Mineral Substances.	1861	82
Engert, A. C.	The Prevention of Smoke	1881	101
„ „	Defects of Steam Boilers and their Remedy.	1884	25
„ „	The Blow-pipe Flame Furnace	1884	185
F.			
Faija, H.	Portland Cement	1885	95
„ „	The Effect of Sea Water on Portland Cement.	1888	39
„ „	Forced Filtration of Water through Concrete.	1889	107
Fell, J. C.	Soft *v.* Hard Water for Manufacturing Purposes.	1884	103
Ferrar, W. G.	Practical Construction in the Colonies	1875	53
Fox, St. G. Lane ..	The Lighting and Extinction of Street Gas Lamps by Electricity.	1878	105
Fox, W. H.	Continuous Railway Brakes	1872	112
„ „	Continuous Railway Brakes	1873	33
Fraser, A.	The Use of the Cornish Pumping Engine.	1864	78
G.			
Gandon, C.	President's Address	1885	1
„ „	Gas Engines	1881	27

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Gibbs, J. D.	The Distribution of Electrical Energy by Secondary Generators.	1885	49
Gore, H.	Modern Gas Works at Home and Abroad.	1868	233
,, ,, ...	Horse Railways and Street Tramways	1873	113
Graham, J.	The most Recent Improvements on the Injector.	1867	266
Greig, A.	Dundee Street Improvements and Drainage of Lochee.	1883	113
Gresham, J.	The most Recent Improvements on the Injector.	1867	266
Grierson, F. W. ..	The National Value of Cheap Patents	1880	145
Griffin, S.	Modern Gas-Engine Practice	1889	169
Griffith, P.	The Treatment and Utilization of Exhaust Steam.	1890	163
H.			
Hakewill, H.	Circular Tables	1865	147
Hall, C. E.	The Conversion of Peat into Fuel and Charcoal.	1876	151
,, ,, ...	Modern Machinery for Preparing Macadam for Roads.	1879	51
Hartley, F. W. ..	Methods employed in the Determination of the Commercial Value and the Purity of Coal Gas.	1869	100
,, ,, ...	An Improved Method of Charging and Drawing Gas Retorts.	1875	185
Hooper, H. R.	The Practice of Foundry Work	1888	191
Horner, J. G.	Certain Methods of Applying Screw Piles in a Bridge at Verona.	1867	52
Horsley, C.	President's Address	1881	1
Hutton, R. J.	The Stability of Chimney Shafts ..	1887	150
J.			
Jacob, A.	The Designing and Construction of Storage Reservoirs.	1866	225
Jensen, P.	Incrustation in Marine Boilers	1866	117
,, ,, ...	Friction in Steam Cylinders	1870	17
Jerram, G. B.	River Pollution caused by Sewage Disposal.	1886	217
Jones, A. W.	Modern Tramway Construction	1879	179
Justice, P. S.	The Dephosphorisation of Iron in the Puddling Furnace.	1885	189
K.			
Kerr, J.	Portable and Pioneer Railways	1891	89
King, G.	Irrigation with Town Sewage	1865	84
Kinsey, W. B.	The Arrangement, Construction, and Machinery of Breweries.	1881	173
Knapp, H. F.	Harbour Bars: their Formation and Removal.	1878	139
Kochs, W. E.	Strength and Rigidity	1865	69

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
L.			
Lailey, C. N.	Acton Main Drainage Works	1888	125
Latham, B.	President's Address	1868	1
” ”	President's Address	1871	1
” ”	The Drainage of the Fens	1862	154
” ”	The Inundations of Marsh Lands ..	1862	173
” ”	The Supply of Water to Towns ..	1864	199
” ”	Utilisation of Sewage	1866	68
” ”	The Application of Steam to the Cultivation of the Soil.	1868	274
” ”	Ventilation of Sewers	1871	39
Lawford, G. M. ..	Fireproof Floors	1889	43
” ”	Drainage of Town Houses	1891	187
Lawford, W.	Light Railways	1888	181
Le Feuvre, W. H. ..	President's Address	1867	1
Le Grand, A.	Tube Wells	1877	133
Light, C. J...	The Need of further Experiments on the Strength of Materials.	1869	194
” ”	A new Method of setting-out the Slopes of Earthworks.	1873	216
” ”	Opening Bridges on the Furness Railway.	1885	119
Lightfoot, T. B. ..	Refrigerating Machinery on Board Ship.	1887	105
” ”	A Trial of a Refrigerating Machine on the Linde System.	1891	39
Louch, J.	Surface Condensers	1861	96
M.			
MacGeorge, W.	President's Address	1874	1
Major, W.	The Priming of Steam-Boilers	1877	59
Martin, W.	The Strength of Flues in Lancashire and similar Boilers.	1882	157
Martin, W. A.	Induced *v.* Forced Draught for Marine Boilers.	1886	111
Matheson, E.	The Quality of Iron, as now used ..	1867	168
” ”	The Accumulator Cotton Press	1868	264
Maude, T.	The Government Brake Trials	1875	129
McNaught, W.	The Rolling of Ships	1876	187
Moore, L. G.	The Explosion at Erith, and the Repair of the River Bank.	1864	183
N.			
Nursey, P. F.	President's Address	1886	1
” ”	The Superheating of Steam, and the various Apparatus employed therein.	1861	36
” ”	Steam Boiler Explosions	1863	1
” ”	Fuel	1864	1
” ”	Sugar-making Machinery	1865	155
” ”	Explosive Compounds for Engineering Purposes.	1869	10
” ”	English and Continental Intercommunication.	1869	154

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
NURSEY, P. F.	Recent Improvements in Explosive Compounds.	1871	108
,, ,, ...	Economic Uses of Blast Furnace Slag	1873	196
,, ,, ...	Mechanical Puddling	1874	77
,, ,, ...	The Channel Railway	1876	17
,, ,, ...	Illumination by means of Compressed Gas.	1881	57
,, ,, ...	Modern Bronze Alloys for Engineering Purposes.	1884	127
,, ,, ...	Primary Batteries for Illuminating Purposes.	1887	185
,, ,, ...	Recent Developments in High Explosives.	1889	71
,, ,, ...	Fox's Patent System of Solid-pressed Steel Waggon and Carriage Frames.	1889	197
,, ,, ...	Pick's System of Manufacturing Salt in Vacuo.	1890	115
O.			
OATES, A.	The Utilisation of Tidal Energy ..	1882	81
O'CONNOR, H.	Machine Stokers for Gas Retorts ..	1891	117
OLANDER, E.	The Enclosure of Lands from the Sea, and the Construction of Sea and other Banks.	1862	25
,, ,, ...	Bridge Floors: Their Design, Strength, and Cost.	1887	27
OLRICK, H.	A new System of Treating Sewage Matter.	1883	23
OLRICK, L.	Marine Governors	1862	104
,, ,, ...	Giffard's Injector	1865	280
P.			
PAGE, G. G.	The Construction of Chelsea Bridge ..	1863	77
PARKES, M.	The Road Bridges of the Charing Cross Railway.	1864	143
,, ,, ...	The Charing Cross Railway Bridge over the Thames.	1864	166
PARSEY, W.	Trussed Beams	1862	52
PAUL, J. H.	Corrosion in Steam Boilers	1891	147
PEARSE, J. W.	The Ventilation of Buildings	1876	97
,, ,, ...	The Mechanical Firing of Steam Boilers.	1877	31
,, ,, ...	Water Purification, Sanitary and Industrial.	1878	29
PENDRED, H. W.	Screw Propellers, their Shafts and Fittings.	1875	151
,, ,, ...	Distilling and Hoisting Machinery for Sea-going Vessels.	1880	55
,, ,, ...	Designs, Specifications, and Inspection of Ironwork.	1883	87
PENDRED, V.	President's Address	1876	1
,, ,, ...	Elastic Railway Wheels	1864	119

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Pendred, V.	The Adhesion of Locomotive Engines, and certain Expedients for increasing or supplementing that Function.	1865	207
,, ,,	Water-tube Boilers	1867	109
,, ,,	Apparatus for Measuring the Velocity of Ships.	1869	215
,, ,,	Examples of Recent Practice in American Locomotive Engineering.	1872	19
Perrett, E.	Filtration by Machinery	1888	106
Phillips, J.	The Forms and Construction of Channels for the Conveyance of Sewage.	1874	145
Pieper, C.	Ice-making Machinery	1882	139
R.			
Reade, S. A.	The Redhill Sewage Works	1868	168
Redman, J. B.	Tidal Approaches and Deep Water Entrances.	1885	143
Rigg, A.	President's Address	1884	1
,, ,,	The Connection between the Shape of heavy Guns and their Durability.	1867	249
,, ,,	The Screw Propeller	1868	202
,, ,,	Sensitiveness and Isochronism in Governors.	1880	73
,, ,,	American Engineering Enterprise	1885	21
,, ,,	Obscure Influences of Reciprocation in High-speed Engines.	1886	83
,, ,,	Balancing of High-speed Steam Engines.	1891	23
Riley, E.	The Manufacture of Iron	1861	59
,, ,,	The Action of Peaty Water on a Boiler	1862	45
Roberts, W.	Steam Fire-engines, and the late Trials at the Crystal Palace.	1863	163
Robinson, H.	President's Address	1887	1
,, ,,	Sewage Disposal	1879	197
Rumble, T. W.	Armour Plates	1861	87
Rymer-Jones, T. M.	Railway Tunnelling in Japan	1882	101
S.			
Sanderson, C.	The Bombay, Baroda, and Central India Railway.	1863	97
Schönheyder, W.	Equalising the Wear in Horizontal Steam Cylinders.	1878	45
Sefi, M.	The Theory of Screw Propulsion	1870	82
Somerville, J.	Charging and Drawing Gas Retorts by Machinery.	1873	138
Spencer, G.	State Railways and Railway Amalgamation.	1872	43
Spice, R. P.	President's Address	1878	1
,, ,,	President's Address	1879	1
,, ,,	Some Modern Improvements in the Manufacture of Coal Gas.	1886	131
Spon, E.	The Use of Paints as an Engineering Material.	1875	69

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Standfield, J.	Floating Docks—the Depositing Dock, and the Double-power Dock.	1881	81
Steel, J.	Air Compression	1876	65
Stephenson, W. H.	Fire-clay Manufactures	1861	17
Stopes, H.	The Engineering of Malting	1884	65
Strachan, G. R.	The Construction and Repair of Roads	1889	17
Suckling, N. J.	Modern Systems of Generating Steam	1874	39
Sugg, W.	Apparatus employed for Illumination with Coal Gas.	1869	134
Sutcliff, R.	Tube Wells for large Water Supplies	1877	149
T.			
Tarbutt, P. F.	Liquid Fuel	1886	193
Thrupp, E. C.	A New Formula for the Flow of Water in Pipes and Open Channels.	1887	224
Trewman, H. C.	Flues and Ventilation	1876	91
Turner, C.	The Timbering of Trenches and Tunnels.	1871	90
Tweddell, R. H.	Direct-Acting Hydraulic Machinery	1877	95
” ”	The Application of Water Pressure to Machine Tools and Appliances.	1890	35
U.			
Usill, G. W.	Rural Sanitation	1877	113
V.			
Varley, S. A.	Railway Train Intercommunication	1873	162
W.			
Walker, J.	Brewing Apparatus	1871	29
Walmisley, A. T.	President's Address	1888	1
” ”	Iron Roofs	1881	123
Wanklyn, J. A.	Cooper's Coal-liming Process	1884	167
Ward. G. M.	The Utilisation of Coal Slack in the Manufacture of Coke for Smelting.	1880	33
Warren, A.	Steam Navigation on the Indus	1863	139
Wessely, C. R. von	Arched Roofs	1866	36
Wilkins, T.	The Machinery and Utensils of a Brewery.	1871	10
Wilson, A. F.	The Manufacture of Coal Gas	1864	35
Wilson, J. W., junr.	The Construction of Modern Piers	1875	29
Wise, F.	Signalling for Land or Naval Purposes.	1863	117
Wise, W. L.	The Patent Laws	1870	45
Worssam, S. W., junr.	Mechanical Saws	1867	196
Y.			
Yarrow, A. F.	Steam Carriages	1862	128
Young, C. F. T.	The Use of Coal in Furnaces without Smoke.	1862	66

SUBJECTS.

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
A.			
Accumulator Cotton Press	E. Matheson	1868	264
Action of Marine Worms and Remedies employed in the Harbour of San Francisco.	J. Blackbourn	1874	111
Action of Peaty Water on a Boiler ..	E. Riley	1862	45
Acton Main Drainage Works	C. N. Lailey	1888	125
Address of President	W. T. Carrington ..	1865	1
” ”	Z. Colburn	1866	1
” ”	W. H. Le Feuvre ..	1867	1
” ”	B. Latham	1868	1
” ”	F. W. Bryant	1869	1
” ”	W. Adams	1870	1
” ”	B. Latham	1871	1
” ”	J. Church	1872	1
” ”	” ”	1873	1
” ”	W. Macgeorge	1874	1
” ”	J. H. Adams	1875	1
” ”	V. Pendred	1876	1
” ”	T Cargill	1877	1
” ”	R. P. Spice	1878	1
” ”	” ”	1879	1
” ”	J. Bernays	1880	1
” ”	C. Horsley	1881	1
” ”	J. Church	1882	1
” ”	” ”	1883	1
” ”	A. Rigg	1884	1
” ”	C. Gandon	1885	1
” ”	P. F. Nursey	1886	1
” ”	Professor H. Robinson	1887	1
” ”	A. T. Walmisley ..	1888	1
” ”	J. R. Baillie	1889	1
” ”	H. Adams	1890	1
” ”	W. N. Colam	1891	1
Adhesion of Locomotive Engines and certain Expedients for Increasing or Supplementing that Function.	V. Pendred	1865	207
Air Compression	J. Steel	1876	65
American Engineering Enterprise ..	A. Rigg	1885	21
American Locomotive Engineering, Examples of recent Practice in	V. Pendred	1872	19
Apparatus for utilising the Waste Heat of Exhaust Steam.	J. Atkinson	1878	167
Apparatus for Measuring the Velocity of Ships.	V. Pendred	1869	15

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Apparatus employed for Illumination with Coal Gas.	W. Sugg	1869	134
Application of Steam to the Cultivation of the Soil.	B. Latham	1868	274
Application of Water Pressure to Machine Tools and Appliances	R. H. Tweddell	1890	35
Arched Roofs	C. von Wessely	1866	36
Armour Plates	T. W. Rumble	1861	87
Arrangement, Construction, and Machinery of Breweries.	W. B. Kinsey	1881	173
Axles, The Strength of Wrought-iron Railway	T. Andrews	1879	143
B.			
Batteries, Primary, for Illuminating Purposes.	P. F. Nursey	1887	185
Blast-furnace Slag, The Economic Uses of	„ „	1873	196
Blasting Charges, The Application of Electricity to the Ignition of	G. G. André	1878	123
Blow-pipe Flame Furnace	A. C. Engert	1884	185
Boilers, Incrustation in Marine	P. Jensen	1866	117
Boilers, Strength of Flues in Lancashire and similar	W. Martin	1882	157
Boilers, The Defects of Steam, and their Remedy.	A. C. Engert	1884	25
Boilers, The Mechanical Firing of Steam	J. W. Pearse	1877	31
Boilers, The Priming of Steam	W. Major	1877	59
Boilers, Water and its Effects on Steam	H. K. Bamber	1867	65
Boilers, Water Tube	V. Pendred	1867	109
Bombay, Baroda, and Central India Railway.	C. Sanderson	1863	97
Brake Trials, The Government	T. Maude	1875	129
Brakes, Continuous Railway	W. H. Fox	1872	112
„ „	„ „	1873	33
Brakes, Hydraulic Continuous and Automatic.	E. D. Barker	1879	75
Brakes, Recent Arrangements of Continuous	St. J. V. Day	1875	87
Breakwater Construction	F. H. Cheesewright ..	1890	83
Breakwaters Floating	T. Cargill	1871	146
Breweries, the Arrangement, Construction, and Machinery of	W. B. Kinsey	1881	173
Brewery, Machinery and Utensils of a	T. Wilkins	1871	10
Brewing Apparatus	J. Walker	1871	29
Bridge, Railway, at the Place de l'Europe, Paris.	T. Cargill	1866	191
Bridge Floors: Their Design, Strength and Cost.	E. Olander	1887	27
Bridge, Construction of Chelsea	G. G. Page	1863	77
Bridge over the Thames, Charing Cross Railway	M. Parkes	1864	166

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Bridges of the Charing Cross Railway, The Road	M. Parkes	1864	143
Bridges, Opening, on the Furness Railway.	C. J. Light	1885	119
Bronze Alloys for Engineering Purposes, Modern	P. F. Nursey	1884	127
Buildings, The Ventilation of	J. W. Pearse	1876	97
C.			
Cable Tramways	W. N. Colam	1885	69
Caissons, Ship, for Dock Basins and Dry Docks.	J. J. F. Andrews	1890	189
Canal between the Atlantic and Pacific Oceans, The Surveys of Proposed Lines for a Ship	Dr. E. Cullen	1868	15
Canal, The Isthmus of Darien and the Ship	,, ,,	1868	52
Carriage Frames, Fox's Patent System of Solid pressed Steel Waggon and	P. F. Nursey	1889	197
Carriages, Steam	A. F. Yarrow	1862	128
Cast-iron, Certain Methods of Treating, in the Foundry.	Z. Colburn	1865	77
Cement, Portland	H. Faija	1885	95
Central India Railway, Bombay, Baroda, and	C. Sanderson	1863	97
Channel Railway, The	P. F. Nursey	1876	17
Channels for the Conveyance of Sewage, The Forms and Construction of	J. Phillips	1874	145
Charcoal, The Conversion of Peat into Fuel and	C. E. Hall	1876	151
Charging and Drawing Gas Retorts by Machinery.	J. Somerville	1873	138
Charging and Drawing Gas Retorts, An Improved Method of	F. W. Hartley	1875	185
Charing Cross Railway Bridge over the Thames.	M. Parkes	1864	166
Charing Cross Railway, The Road Bridges of	,, ,,	1864	143
Cheap Patents, The National value of	F. W. Grierson	1880	145
Chelsea Bridge, The Construction of	G. G. Page	1863	77
Chimney Shafts, Stability of	R. J Hutton	1887	150
Circular Tables	H. Hakewill	1865	147
Coal Gas, The methods employed in the determination of the Commercial Value and Purity of	F. W. Hartley	1869	100
Coal Gas, Apparatus employed for illumination with	W. Sugg	1869	134
Coal Gas, The Manufacture of	A. F. Wilson	1864	35
Coal Gas, Modern Manufacture	C. C. Carpenter	1891	61
Coal Gas, Some Modern Improvements in the Manufacture of	R. P. Spice	1886	131
Coal-liming Process, Cooper's	J. A. Wanklyn	1884	167
Coal Mines, The Ventilation of	G. G. André	1874	23

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Coal Slack, Utilisation of, in the Manufacture of Coke for Smelting.	G. M. Ward	1880	33
Colliery, The Underground Pumping Machinery at the Erin, Westphalia	H. Davey	1876	119
Colonies, Practical Construction in the	W. G. Ferrar	1875	53
Compressed Gas, Illumination by means of	P. F. Nursey	1881	57
Compression, Air	J. Steel	1876	65
Concrete, Forced Filtration of Water Through	H. Faija	1889	107
Condensers, Surface	J. Louch	1861	96
Connection between the Shape of Heavy Guns and their Durability.	A. Rigg	1867	249
Construction, The, and Repair of Roads	G. R. Strachan	1889	17
Construction, Modern Tramway	A. W. Jones	1879	79
Construction, Modern Roadway	H. S. Copland	1878	61
Construction of Chelsea Bridge	G. G. Page	1863	77
Construction of Modern Piers	J. W. Wilson, junr.	1875	29
Continental Intercommunication, English and	P. F. Nursey	1869	154
Continuous and Automatic Brakes, Hydraulic	E. D. Barker	1879	75
Continuous Brakes, Recent arrangements of	St. J. V. Day	1875	87
Continuous Railway Brakes	W. H. Fox	1872	112
" " "	" "	1873	33
Conversion of Peat into Fuel and Charcoal	C. E. Hall	1876	151
Cooper's Coal-liming Process	J. A. Wanklyn	1884	167
Cornish Pumping Engine, The Use of the	A. Fraser	1864	78
Corrosion in Steam Boilers	J. H. Paul	1891	147
Cotton Press, The Accumulator	E. Matheson	1868	264
Cylinders, Equalising the wear in Horizontal Steam	W. Schönheyder	1878	45
Cylinders, Friction in Steam	P. Jensen	1870	17
Cyprus, Engineering Notes on	C. J. Alford	1880	131
D.			
Darien and the Ship Canal, The Isthmus of	Dr. E. Cullen	1868	52
Deep-Sea Lighthouses, Feasibility, and Construction of	C. Anderson	1883	45
Deep-water Entrances, Tidal Approaches and	J. B. Redman	1885	143
Defects of Steam Boilers and their Remedy.	A. C. Engert	1884	25
Dephosphorisation of Iron in the Puddling Furnace.	P. S. Justice	1885	169
Design, Strength, and Cost of Bridge Floors.	E. Olander	1887	27
Designing and Construction of Storage Reservoirs, The	A. Jacob	1866	225

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Designs, Specifications, and Inspection of Ironwork.	H. W. Pendred	1883	87
Direct-acting Hydraulic Machinery ..	R. H. Tweddell	1877	95
Direct-acting Pumping Engines ..	P. B. Björling	1877	79
Disposal of Sewage, The	H. Robinson	1879	197
Distilling and Hoisting Machinery for Sea-going Vessels.	H. W. Pendred	1880	55
Distribution of Electrical Energy by Secondary Generators.	J. D. Gibbs	1885	49
Dock Basins and Dry Docks, Ship Caissons for.	J. J. F. Andrews ..	1890	189
Docks, Floating.—The Depositing Dock and the Double-power Dock.	J. Standfield	1881	81
Drainage and Water Supply to the Town of Fareham.	T. Buckham	1869	41
Drainage of Town Houses	G. M. Lawford	1891	187
Drainage Works, Main, Acton	C. N. Lailey	1888	125
Drainage of the Fens, The	B. Latham	1862	154
Dundee Street Improvements and Drainage of Lochee.	A. Greig	1883	113
E.			
Earthworks, A New Method of setting out the Slopes of	C. J. Light	1873	216
Economics of Railway Maintenance ..	E. S. Crompton	1870	101
Economic Uses of Blast Furnace Slag	P. F. Nursey	1873	196
Effect of Sea Water on Portland Cement	H. Faija	1888	39
Elastic Railway Wheels	V. Pendred	1864	119
Electric Light Engineering, Notes on ..	C. H. W. Biggs and W. W. Beaumont	1882	23
Electric Telegraph Instruments	E. G. Bartholomew ..	1872	53
Electric Telegraphy, irrespective of Telegraphic Apparatus.	" " ..	1869	55
Electrical Batteries	" " ..	1872	77
Electrical Energy, Distribution of, by Secondary Generators.	J. D. Gibbs	1885	49
Electricity, The application of, to the ignition of Blasting Charges.	G. G. André	1878	123
Electricity, The Lighting and Extinction of Street Gas Lamps by	St. G. Lane Fox ..	1878	105
Enclosure of Lands from the Sea, and the Construction of Sea and other banks.	E. Olander	1862	25
Engineering Enterprise, American ..	A. Rigg	1885	21
Engineering Notes on Cyprus	C. J. Alford	1880	131
Engineering in India	F. C. Danvers	1868	137
Engineering of Malting..	H. Stopes	1884	65
Engines, Direct-acting Pumping	P. B. Björling	1877	79
Engines for Mines, Recent Improvements in Pumping	H. Davey	1873	182
Engines for Town Water Supply, Pumping	" "	1867	88
Engines, Gas	C. Gandon	1881	27
Engines, Obscure Influences of Reciprocation in High Speed	A. Rigg	1886	83

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Engines on the Rimutakai Incline, New Zealand, The Fell	R. J. Alford	1882	121
Engines, Steam Fire, and the late trial at the Crystal Palace.	W. Roberts..	1863	163
Engines, The Adhesion of Locomotive, and certain expedients for increasing or supplementing that Function.	V. Pendred	1865	207
Engines, The Use of the Cornish Pumping	A. Fraser	1864	78
English and Continental Intercommunication.	P. F. Nursey	1869	154
Equalising the Wear in Horizontal Steam Cylinders.	W. Schönheyder ..	1878	45
Examples of Recent Practice in American Locomotive Engineering.	V. Pendred..	1872	19
Exhaust Steam, Apparatus for Utilising the Waste Heat of	J. Atkinson	1878	167
Exhaust Steam, Treatment and Utilisation of.	P. Griffith	1890	163
Exhibitions as Aids to Engineering Progress, Value of The	S. Barnett, junr. ..	1883	75
Experimental Researches into the Nature and Action of Steam Boilers.	T. Baldwin	1867	23
Experiments on the Strength of Materials, The Need of further	C. J. Light..	1869	194
Explosion at Erith, and the Repair of the River Bank.	L. G. Moore	1864	183
Explosions, Steam Boiler	P. F. Nursey	1863	1
Explosive Compounds for Engineering Purposes.	„ „	1869	10
Explosive Compounds, Recent Improvements in	„ „	1871	108
Explosives, High, Recent Developments in	„ „	1889	75
F.			
Fareham, Drainage and Water Supply of the Town of	T. Buckham	1869	41
Feasibility and Construction of Deep-sea Lighthouses.	C. Anderson	1883	45
Fell Engines on the Rimutakai Incline, New Zealand.	R. J. Alford	1882	121
Fens, The Drainage of the	B. Latham	1862	154
Filtration by Machinery	E. Perrett	1888	106
Filtration, Forced, of Water through Concrete	H. Faija	1889	107
Fire-clay Manufactures..	W. H. Stevenson ..	1861	17
Fire Engines, Steam	W. Roberts..	1863	163
Fireproof Floors	G. M. Lawford	1889	43
Floating Breakwaters	T. Cargill	1871	146
Floating Docks: The Depositing Dock and the Double-power Dock.	J. Standfield	1881	81
Floors, Fireproof	G. M. Lawford	1889	43

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Flow of Water, New Formula for, in Pipes and Open Channels.	E. C. Thrupp	1887	224
Flues and Ventilation	A. H. C. Trewman	1876	91
Flues in Lancashire and similar Boilers, The Strength of	W. Martin	1882	157
Forms and Construction of Channels for the Conveyance of Sewage.	J. Phillips	1874	145
Foundry Work, Practice of	H. R. Hooper	1888	191
Fox's Patent System of Solid-pressed Steel Waggon and Carriage Frames.	P. F. Nursey	1889	197
Friction in Steam Cylinders	P. Jensen	1870	17
Friction of the Slide Valve and its Appendages.	T. Adams	1866	6
Fuel	P. F. Nursey	1864	1
Fuel and Charcoal, The Conversion of Peat into	C. E. Hall	1876	151
Fuel, Liquid	P. F. Tarbutt	1886	193
Furnace, The Blowpipe Flame	A. C. Engert	1884	185
G.			
Gas, Apparatus employed for Illumination with Coal	W. Sugg	1869	134
Gas Engines	C. Gandon	1881	27
Gas-Engine, Modern, Practice	S. Griffin	1889	169
Gas, Illumination by means of Compressed	P. F. Nursey	1881	57
Gas, Modern Improvements in the Manufacture of Coal	R. P. Spice	1886	131
Gas Retorts, An Improved Method of Charging and Drawing	F. W. Hartley	1875	185
Gas Retorts, Charging and Drawing by Machinery.	J. Somerville	1873	138
Gas Retorts, Machine Stokers for	H. O'Connor	1891	117
Gas, The Manufacture of Coal	A. F. Wilson	1864	35
Gas, The Methods employed in the determination of the Commercial Value and Purity of Coal	F. W. Hartley	1869	100
Gas and Water Mains, The Prevention of Leakage in	C. M. Barker	1869	79
Gas Works at Home and Abroad, Modern	H. Gore	1868	233
Giffard's Injector	L. Olrick	1865	280
Government Brake Trials	T. Maude	1875	129
Governors, Marine	L. Olrick	1862	104
Governors, Sensitiveness and Isochronism in	A. Rigg	1880	73
Guns, The connection between the Shape of Heavy, and their Durability.	„ „	1867	249
H.			
Harbour Bars: their Formation and Removal.	H. F. Knapp	1878	139

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Hauling Machinery, The new Pit and, for the San Domingos Mine in Portugal.	J. Bernays	1879	29
High Pressure Steam and Steam Engine Efficiency.	W. W. Beaumont	1888	221
Horse Railways and Street Tramways.	H. Gore	1873	113
Houses, Town, Drainage of	G. M. Lawford	1891	187
Hydraulic Continuous and Automatic Brakes.	E. D. Barker	1879	75
Hydraulic Experiments, the Roorkee	E. S. Bellasis	1886	41
Hydraulic Machinery, Direct-acting	R. H. Tweddell	1877	95
I.			
Ice-making Machinery	C. Pieper	1882	139
Ignition of Blasting Charges, The application of Electricity to	G. G. André	1878	123
Illumination by means of Compressed Gas.	P. F. Nursey	1881	57
Illumination with Coal Gas, Apparatus employed for	W. Sugg	1869	134
Improved Method of Charging and Drawing Gas Retorts.	F. W. Hartley	1875	185
Improvements in Explosive Compounds, Recent	P. F. Nursey	1871	108
Improvements in Pumping-engines for Mines, Recent	H. Davey	1873	182
Improvements in Tin Dressing Machinery, Recent	S. H. Cox	1874	11
Incrustation in Marine Boilers	P. Jensen	1866	117
India, Engineering in	F. C. Danvers	1868	137
Induced *v.* Forced Draught for Marine Boilers.	W. A. Martin	1886	111
Indus, Steam Navigation on the	A. Warren	1863	139
Injector, Giffard's	L. Olrick	1865	280
Injector, The most Recent Improvements on the	J. Gresham	1867	266
Instruments, Electric Telegraph	E. G. Bartholomew	1872	53
Intercommunication, English and Continental	P. F. Nursey	1869	154
Intercommunication, Railway Train	S. A. Varley	1873	162
International System of Marine Course Signalling.	Capt. W. B. Barker	1884	47
Inundations of Marsh Land	B. Latham	1862	173
Iron, The Dephosphorisation of, in the Puddling Furnace.	P. S. Justice	1885	169
Iron, The Manufacture of	E. Riley	1861	59
Iron, The relation between the Safe Load and ultimate Strength of	Z. Colburn	1863	35
Iron, The quality of, as now used	E. Matheson	1867	168
Iron Roofs	A. T. Walmisley	1881	123
Iron and Steel Surfaces, The Preservation and Ornamentation of	G. Bower	1883	59
Ironwork, Designs, Specifications, and Inspection of	H. W. Pendred	1883	87

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Irrigation with Town Sewage	G. King	1865	84
Isochronism in Governors, Sensitiveness and	A. Rigg	1880	73
Isthmus of Darien and the Ship Canal	Dr. E. Cullen	1868	52
J.			
Japan, Railway Tunnelling in	T. M. Rymer-Jones ..	1881	101
Joints, Single- and Double-rivetted ..	T. Baldwin	1866	150
L.			
Land and Naval Purposes, Signalling for	F. Wise	1863	117
Lartigue Single-rail Railway, The ..	F. B. Behr	1886	163
Laws, Decrees and Regulations relating to Mining Operations in the old kingdom of Sardinia.	C. J. Alford	1879	106
Leakage in Gas and Water Mains, The prevention of	C. M. Barker	1869	79
Light Railways	W. Lawford	1888	181
Lighthouses, The feasibility and construction of Deep-sea	C. Anderson	1883	45
Lighting and Extinction of Street Gas-Lamps by Electricity.	St. G. Lane Fox ..	1878	105
Linde System, Trial of a Refrigerating Machine on the	T. B. Lightfoot.. ..	1891	39
Liquid Fuel	P. F. Tarbutt	1886	193
Lochee, Dundee Street Improvements and Drainage of	A. Greig	1883	113
Locomotive Engineering, Examples of recent Practice in American	V. Pendred..	1872	19
Locomotive Engines, The adhesion of..	„ „	1865	207
M.			
Macadam for Roads, Modern Machinery for preparing	C. E. Hall	1879	51
Machine, Refrigerating, on the Linde System, Trial of	T. B Lightfoot	1891	39
Machinery, Refrigerating, on Board Ship.	T. B. Lightfoot	1887	105
Machinery, Filtration by	E. Perrett	1888	106
Machinery and Utensils of a Brewery..	T. Wilkins	1871	10
Machine Stokers for Gas Retorts.. ..	H. O'Connor	1891	117
Machine Tools and Appliances, application of Water Pressure to	R. H. Tweddell.. ..	1890	35
Machinery, Weighing, and Automatic Apparatus in connection therewith.	W. H. Brothers.. ..	1890	55
Main Drainage and Sewage Disposal Works, Wimbledon	W. S. Crimp	1888	73
Main Drainage Works, Acton	C. N. Lailey.	1888	125
Maintenance, The Economics of Railway	E. S. Crompton ..	1870	101
Malting, The Engineering of	H. Stopes	1884	65

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Manufacture, Modern Coal Gas	C. C. Carpenter	1891	61
Manufacture of Coal Gas	A. F. Wilson	1864	35
Manufacture of Iron	E. Riley	1861	59
Marine Boilers, Incrustation in	P. Jensen	1866	117
Marine Boilers, Induced *v.* Forced Draught for	W. A. Martin	1886	111
Marine Course Signalling, International system of	Capt. W. B. Barker	1884	47
Marine Governors	L. Olrick	1862	104
Marine Worms, Action of and Remedies for, at San Francisco.	J. Blackbourn	1874	111
Marsh Lands, The Inundations of	B. Latham	1862	173
Mechanical Firing of Steam Boilers	J. W. Pearse	1877	31
Mechanical Puddling	P. F. Nursey	1874	77
Mechanical Saws	S. W. Worssam, junr.	1867	196
Methods employed in the Determination of the Commercial Value and Purity of Coal Gas.	F. W. Hartley	1869	100
Milford Haven and its New Pier Works.	H. Davey	1872	89
Milling Machinery, Roller	J. H. Carter	1883	125
Mineralogy of the Island of Sardinia	C. J. Alford	1879	93
Mining Operations in the old kingdom of Sardinia, Laws, &c., relating to	,, ,,	1879	106
Modern Bronze Alloys for Engineering purposes.	P. F. Nursey	1884	127
Modern Coal Gas Manufacture	C. C. Carpenter	1891	61
Modern Gas-Engine Practice	S. Griffin	1889	169
Modern Gasworks at Home and Abroad	H. Gore	1868	233
Modern Improvements in the Manufacture of Coal Gas.	R. P. Spice	1886	131
Modern Roadway Construction	H. S. Copland	1878	61
Modern Steel as a Structural Material	W. W. Beaumont	1880	109
Modern Systems of Generating Steam	N. J. Suckling	1874	39
Modern Tramway Construction	A. W. Jones	1879	179
N.			
National Value of Cheap Patents	F. W. Grierson	1880	145
Navigation on the Indus, Steam	A. Warren	1863	139
Need of further Experiments on the Strength of Materials.	C. J. Light	1869	194
New Formula for the Flow of Water in Pipes and Open Channels.	E. C. Thrupp	1887	224
Notes on Cyprus, Engineering	C. J. Alford	1880	131
Notes on Electric Light Engineering	C. H. W. Biggs and W. W. Beaumont	1882	23
O.			
Obituary	.. ..	1887	265
,,	.. ..	1888	253
,,	.. ..	1889	219
,,	.. ..	1890	211
,,	.. ..	1891	215

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Obscure Influences of Reciprocation in High-speed Engines.	A. Rigg	1886	83
Opening Bridges on the Furness Railway.	C. J. Light	1885	119
P.			
Paints, The Use of, as an Engineering Material.	E. Spon	1875	69
Panama Railroad, The	Dr. E. Cullen	1868	39
Paris Exhibition, Visit to the	.. ..	1867	151
Patent Laws, The	C. D. Abel	1865	25
„ „ „	W. L. Wise	1870	45
Patents, The National Value of Cheap	F. W. Grierson	1880	145
Peat, The Conversion of, into Fuel and Charcoal.	C. E. Hall	1876	151
Peaty water, The Action of, on a Boiler	E. Riley	1862	45
Pick's System of Manufacturing Salt in Vacuo.	P. F. Nursey	1890	115
Piers, The Construction of Modern ..	J. W. Wilson, junr. ..	1875	29
Pier Works, Milford Haven and its New	H. Davey	1872	89
Pin-connected *v.* Rivetted Bridges ..	J. H. Cunningham ..	1889	131
Pioneer and Portable Railways	J. Kerr	1891	89
Pits and Hauling Machinery for the San Domingos Mines in Portugal.	J. Bernays	1879	29
Portable and Pioneer Railways	J. Kerr	1891	89
Portland Cement	H. Faija	1885	95
Portland Cement, Effect of Sea Water on	„ „	1888	39
Practical Construction in the Colonies	W. G. Ferrar	1875	53
Practice of Foundry Work	H. R. Hooper	1888	191
Preservation and Ornamentation of Iron and Steel Surfaces.	G. Bower	1883	59
Prevention of Smoke	A. C. Engert	1881	101
Prevention of Leakage in Gas and Water Mains.	C. M. Barker	1869	79
Primary Batteries for Illuminating Purposes.	P. F. Nursey	1887	185
Priming of Steam Boilers	W. Major	1877	59
Propeller, The Screw	A. Rigg	1868	202
Propellers, Screw; their Shafts and Fittings.	H. W. Pendred	1875	151
Propulsion, The Theory of Screw ..	M. Sefi	1870	82
Puddling Furnace, The Dephosphorisation of Iron in	P. S. Justice	1885	169
Puddling, Mechanical	P. F. Nursey	1874	77
Pumping Engine, The Use of the Cornish	A. Fraser	1864	78
Pumping Engines, Direct-acting ..	P. B. Björling	1877	79
Pumping Engines for Mines, Recent Improvements in	H. Davey	1873	182
Pumping Engines for Town Water Supply.	„ „	1867	88
Pumping Machinery, The Underground, at the Erin Colliery, Westphalia.	„ „	1876	119

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Q.			
Quality of Iron, as now used	E. Matheson	1867	168
R.			
Railway Amalgamation, State Railways and	G. Spencer	1872	43
Railway Axles, The Strength of Wrought-iron	T. Andrews	1879	143
Railway Brakes, Continuous	W. H. Fox	1872	112
" " "	" "	1873	33
Railway Bridge at the Place de l'Europe, Paris.	T. Cargill	1866	191
Railway Bridge over the Thames, The Charing Cross.	M. Parkes	1864	166
Railway Maintenance, The Economics of	E. S. Crompton	1870	101
Railway, The Channel	P. F. Nursey	1876	17
Railway Train Intercommunication ..	S. A. Varley	1873	162
Railway Tunnelling in Japan	T. M. Rymer-Jones ..	1882	101
Railway Wheels, Elastic	V. Pendred	1864	119
Railways, Horse, and Street Tramways	H. Gore	1873	113
Railways, Light	W. Lawford	1888	181
Railways, Portable and Pioneer	J. Kerr	1891	89
Recent Developments in High Explosives.	P. F. Nursey	1889	71
Reciprocation, Obscure Influences of, in High-speed Engines.	A. Rigg	1886	83
Redhill Sewage Works, The	S. A. Reade	1868	168
Refrigerating Machine on the Linde System, Trial of	T. B. Lightfoot	1891	39
Refrigerating Machinery on Board Ship.	T. B. Lightfoot	1887	105
Relation between the Safe Load and ultimate Strength of Iron.	Z. Colburn	1863	35
Renewal of Roof over Departure Platform at King's Cross Terminus, G.N.R.	R. M. Bancroft	1887	125
Repair of the River Bank, The Explosion at Erith and the	L. G. Moore	1864	183
Reservoirs, Storage, The Designing and Construction of	A. Jacob	1866	225
Rigidity, Strength and	W. E. Kochs	1865	69
River Pollution caused by Sewage Disposal.	G. B. Jerram	1886	217
Rivetted, Pin-connected Bridges v. ..	J. H. Cunningham ..	1889	135
Road Bridges of the Charing Cross Railway.	M. Parkes	1864	143
Roads, The Construction and Repair of	G. R. Strachan	1889	17
Roadway Construction, Modern	H. S. Copland	1878	61
Roller-milling Machinery	J. H. Carter	1883	125
Rolling of Ships	W. McNaught	1876	187
Roof, Renewal of, over Departure Platform at King's Cross Terminus, G.N.R.	R. M. Bancroft	1887	125

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Roofs, Arched	C. R. von Wessely	1866	36
Roofs, Iron	A. T. Walmisley	1881	123
Roorkee Hydraulic Experiments	E. S. Bellasis	1886	41
Rural Sanitation	G. W. Usill	1877	113
S.			
Safe Load and Ultimate Strength of Iron, Relation between	Z. Colburn	1863	35
Safety Valves for Steam Boilers, &c.	T. Baldwin	1867	23
Salt, Pick's System of Manufacturing, in Vacuo.	P. F. Nursey	1890	
Sanitary and Industrial, Water Purification	J. W. Pearse	1878	29
Sardinia, The Mineralogy of the Island of	C. J. Alford	1879	93
Saws, Mechanical	S. W. Worssam, junr.	1867	196
Screw Piles in the Construction of a Wrought-iron Bridge at Verona.	J. G. Horner	1867	52
Screw Propeller, The	A. Rigg	1868	202
Screw Propellers, their Shafts and Fittings.	H. W. Pendred	1875	151
Screw Propulsion, The Theory of	M. Sefi	1870	82
Sea and other Banks, The Construction of	E. Olander	1862	25
Sea Water, Effect of, on Portland Cement.	H. Faija	1888	39
Secondary Generators, Distribution of Electrical Energy by	J. D. Gibbs	1885	49
Sensitiveness and Isochronism in Governors.	A. Rigg	1880	73
Sewage Disposal	H. Robinson	1879	197
Sewage Disposal, River Pollution caused by	G. B. Jerram	1886	217
Sewage Disposal Works, and Main Drainage, Wimbledon.	W. S. Crimp	1888	73
Sewage, Irrigation with Town	G. King	1865	84
Sewage Matter, A new System of treating	H. Olrick	1883	23
Sewage, The Forms and Construction of Channels for the Conveyance of	J. Phillips	1874	145
Sewage, Utilisation of	B. Latham	1866	68
Sewage Works, Redhill	S. A. Reade	1868	168
Sewerage System, The Shone Hydro-Pneumatic.	E. Ault	1887	68
Sewer Ventilation	W. S. Crimp	1890	139
Sewers, Ventilation of	B. Latham	1871	39
Ship Caissons for Dock Basins and Dry Docks.	J. J. F Andrews	1890	189
Ship Canal between the Atlantic and Pacific Oceans, The Surveys for	Dr. E. Cullen	1868	15
Ship Canal, The Isthmus of Darien and the	,, ,,	1868	52
Ships, Apparatus for Measuring the Velocity of	V. Pendred	1869	215

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Ships, The Rolling of	W. McNaught	1876	187
Shone Hydro-Pneumatic Sewerage System.	E. Ault	1887	68
Signalling for Land and Naval purposes	F. Wise	1863	117
Single and Double-rivetted Joints	T. Baldwin	1866	150
Slag, The Economic Use of Blast-furnace	P. F. Nursey	1873	196
Slide-valve, The Friction of, and its appendages.	T. Adams	1866	6
Slopes of Earthwork, A new Method of Setting-out.	C. J. Light	1873	216
Smoke, Prevention of	A. C. Engert	1881	101
Soft *v.* Hard Water for Manufacturing purposes.	J. C. Fell	1884	103
Soil, Application of Steam to the Cultivation of the	B. Latham	1868	274
Stability of Chimney Shafts	R. J. Hutton	1887	150
State Railways and Railway Amalgamation.	G. Spencer	1872	43
Steam, Apparatus for Utilising the Waste Heat of Exhaust	J. Atkinson	1878	167
Steam Boilers, Corrosion in	J. H. Paul	1891	147
Steam Boilers, The Defects of, and their Remedy.	A. C. Engert	1884	25
Steam Boiler Explosions	P. F. Nursey	1863	1
Steam Boilers, Experimental Researches into the Nature and Action of	T. Baldwin	1867	23
Steam Boilers, The Primiug of	W. Major	1877	59
Steam Boilers, Mechanical Firing of	J. W. Pearse	1877	31
Steam Boilers, Water and its effect on	H. K. Bamber	1867	65
Steam Carriages	A. F. Yarrow	1862	128
Steam Cylinders, Equalising the Wear in Horizontal	W. Schönheyder	1878	45
Steam Cylinders, Friction in	P. Jensen	1870	17
Steam Fire Engines, and the late trial at the Crystal Palace.	W. Roberts	1863	163
Steam, High Pressure, and Steam Engine Efficiency.	W. W. Beaumont	1888	221
Steam, Modern Systems of Generating	N. J. Suckling	1874	39
Steam Navigation on the Indus	A. Warren	1863	139
Steel, Modern, as a Structural Material	W. W. Beaumont	1880	109
Steel Waggon and Carriage Frames, Fox's System of Solid-pressed	P. F. Nursey	1889	197
Stokers, Machine, for Gas Retorts	H. O'Connor	1891	117
Stone-sawing Machinery	H. Conradi	1876	135
Storage Reservoirs, Designing and Construction of	A. Jacob	1866	225
Street Tramways, Horse Railways and	H. Gore	1873	113
Strength and Rigidity	W. E. Kochs	1865	69
Strength of Flues in Lancashire and similar Boilers.	W. Martin	1882	157
Strength of Materials, Need of further Experiments on the	C. J. Light	1869	194
Strength of Wrought-iron Railway Axles.	T. Andrews	1879	143

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Sugar-making Machinery	P. F. Nursey	1865	155
Super-heating of Steam, and the various Appliances employed therein.	„ „	1861	36
Supply of Water to Towns	B. Latham	1864	199
Surface Condensers	J. Louch	1861	96
T.			
Tables, Circular	H. Hakewill	1865	147
Telegraph Instruments, Electric	E. G. Bartholomew	1872	53
Telegraphy, Electric, irrespective of Telegraphic apparatus.	„ „	1869	55
Testimonial to Mr. Alfred Williams		1868	161
Theory of Screw Propulsion	M. Sefi	1870	82
Tidal Approaches and Deep-water Entrances.	J. B. Redman	1885	143
Tidal Energy, Utilisation of	A. Oates	1882	81
Timbering of Trenches and Tunnels	C. Turner	1871	90
Tin-dressing Machinery, Recent Improvements in	S. H. Cox	1874	11
Town Houses, Drainage of	G. M. Lawford	1891	187
Town Sewage, Irrigation with	G. King	1865	84
Towns, Supply of Water to	B. Latham	1864	199
Town Water Supply, Pumping Engines for	H. Davey	1867	88
Tramway Construction, Modern	A. W. Jones	1879	179
Tramway Rolling Stock, and Steam in connection therewith.	C. C. Cramp	1874	119
Tramways, Cable	W. N. Colam	1885	69
Treating Sewage Matter, A new system of	H. Olrick	1883	23
Treatment and Utilisation of Exhaust Steam.	P. Griffith	1890	163
Trial of a Refrigerating Machine on the Linde System.	T. B. Lightfoot	1891	39
Trussed Beams	W. Parsey	1862	52
Tube Wells	A. Le Grand	1877	133
Tube Wells for large Water Supply	R. Sutcliff	1877	149
Tunnelling, Railway, in Japan	T. M. Rymer-Jones	1882	101
Tunnels, Timbering of Trenches and	C. Turner	1871	90
U.			
Underground Pumping Machinery at the Erin Colliery, Westphalia.	H. Davey	1876	119
Use of Coal in Furnaces without Smoke	C. F. T. Young	1862	66
Utensils of a Brewery, Machinery and	T. Wilkins	1871	10
Utilisation of Coal Slack in the Manufacture of Coke for Smelting.	G. M. Ward	1880	33
Utilisation of Sewage	B. Latham	1866	68
Utilisation of Tidal Energy	A. Oates	1882	81
Utilisation of Waste Mineral Substances.	E. Edwards	1861	82

Subject of Paper.	Author.	Transactions. Year.	Transactions. Page.
V.			
Vacation Visits	.. ..	1878	119
„ „	.. ..	1879	141
„ „	.. ..	1880	89
„ „	.. ..	1881	121
„ „	.. ..	1882	119
„ „	..	1883	85
„ „	.. ..	1884	119
„ „	.. ..	1885	113
„ „	.. ..	1886	153
„ „	.. ..	1887	145
„ „	.. ..	1888	148
„ „	.. ..	1889	131
„ „	.. ..	1890	133
„ „	.. ..	1891	111
Value of Exhibitions as Aids to Engineering Progress.	S. Barnett, junr. ..	1883	75
Value of Cheap Patents, The National	E. W. Grierson	1880	145
Velocity of Ships, Apparatus for Measuring the	V. Pendred	1869	215
Ventilation, Flues and	A. H. C. Trewman ..	1876	91
Ventilation of Buildings	J. W. Pearse	1876	97
Ventilation of Coal Mines	G. G. André	1874	23
Ventilation of Sewers	B. Latham	1871	39
Ventilation, Sewer	W. S. Crimp	1890	139
Verona, Screw Piles in the construction of wrought-iron Bridge at	J. G. Horner	1867	52
Visit to the Paris Exhibition	.. ..	1867	151
W.			
Waggon and Carriage Frames, Fox's Patent System of Solid-pressed Steel,	P. F. Nursey	1889	197
Waste Heat of Exhaust Steam, Apparatus for Utilising the	J. Atkinson	1878	167
Waste Mineral Substances, The Utilisation of	E. Edwards	1861	82
Water and its effects on Steam Boilers ..	H. K. Bamber	1867	65
Water Pressure, Application of, to Machine Tools and Appliances.	R. H. Tweddell	1890	35
Water Purification, Sanitary and Industrial.	J. W. Pearse	1878	29
Water, Soft v. Hard, for Manufacturing purposes.	J. C. Fell	1884	103
Water, Supply of, to Towns	B. Latham	1864	199
Water Supply, Pumping-engines for Town	H. Davey	1867	88
Water Supply to the Town of Fareham, Drainage and	T. Buckham	1869	41
Water-tube Boilers	V. Pendred	1867	109
Wear in Horizontal Steam Cylinders, Equalising the	W. Schönheyder ..	1878	45

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Weighing Machinery and Automatic Apparatus in connection therewith.	W. H. Brothers	1890	55
Wells, Tube	A. Le Grand	1877	133
Wells, Tube, for large Water Supply ..	R. Sutcliff	1877	149
Wheels, Elastic Railway	V Pendred	1864	119
Wimbledon Main Drainage and Sewage Disposal Works.	W. S. Crimp	1888	73
Worms, The Action of Marine, and Remedies employed in the Harbour of San Francisco.	J. Blackbourn	1874	111

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